ANNALS OF SURGERY

VOL. LIV OCTOBER, 1911 No. 4

ORIGINAL MEMOIRS.

A STUDY OF THE INFECTIONS.*

BY ALGERNON T. BRISTOW, M.D.,

OF BROOKLYN, NEW YORK.

Clinical Professor of Surgery at the Long Island College Hospital.

HOSPITAL laboratories have for many years devoted their energies to the study of morbid tissues, but only occasionally to the bacterial origin of the infections. The desultory work which has been done has been in a few large hospitals connected with teaching institutions and a few others with ample means and a large laboratory staff. The study of infections from the bacteriological standpoint has not received the importance which it deserves. With the discoveries of Sir Almeroth Wright, however, and application of his principles to the creation of an artificial immunity in individual infections, the bacteriology of surgical diseases assumes new significance.

Important as the study of tissues undoubtedly is, particularly from the diagnostic standpoint, the study of the infections assumes at least equal importance, more particularly, however, from the viewpoint of therapeutics which is, after all, the goal of our art. The chief reason for the relative neglect of this important branch of hospital work has been, no doubt, the enormous amount of time which such investigations require. The average hospital pathologist, sometimes paid, more often unpaid, has quite enough to occupy

* Read before the American Surgical Association, June 19, 1911.

himself with the tedious preparation of morbid tissues for the final judgment of the microscope without dabbling in the mazes of bacteriological work. If this branch of pathology is to receive the attention which its importance deserves, we shall have to add to our hospital staff a paid bacteriologist, who shall have nothing else to occupy his time save the hunting down of infection and the making of vaccines. From the writer's experience of more than three years with vaccines, it is his opinion that Wright's work has added a most valuable weapon to our armamentarium against disease. We have only begun to know how to use bacterial products. We are but on the threshold of our investigations into the problems which are involved in the production of artificial immunity. Antisepsis and asepsis secured us to a wonderful degree against wound infections following the surgeon's knife. Wright's methods promise a victory over primary infections against which our only remedies hitherto have been incision, drainage, and the natural resistance of the patient, which has too frequently proved insufficient to the task.

A case of primary infection which occurred in the writer's service two years ago emphasized most strongly the prime importance of the fact that in each infection the bacteriological source should be traced. The case has been published in full in the *New York State Journal of Medicine*, but may be briefly referred to here.

In March, 1909, an Italian came into the writer's service at the Long Island College Hospital with a sinus leading down to some carious bone at the angle of the jaw. No cultures were taken previous to operation, and there was nothing to indicate the presence of anything unusual. Operation was done and the carious bone removed. The reaction to operation was somewhat severe but subsided and the sinus closed without incident, nor was there ever any serious infection of the face. A week subsequent to the operation the man began to complain of atrocious pains in the calves of the legs. Finally it was evident that an abscess had formed in the left calf, and it was opened and found to contain grumous bloody pus. Through the

courtesy of the Hoagland Laboratory, cultures from the pus were taken at the time of the drainage. Subsequently a similar suppurative process occurred in the right forearm. The infecting organism, to the astonishment of everybody concerned, proved to be that of glanders, of which the patient had not a single symptom. There were no farcy buds, no nasal discharge, nothing save the suppurative processes in the left leg and right arm, which did not differ from ordinary metastatic foci, excepting the grumous character of the pus, which, while a feature of the suppuration of glanders, also occurs in other infections, being ordinarily simply an evidence of a low grade of resistance on the part of infected tissues.

Time does not here serve to go into the case at length. It was fully reported in the May, 1910, number of the *New York State Journal of Medicine* by the writer, the laboratory work being described by Dr. Benjamin White, the director of the Hoagland Laboratory. Suffice it to say that the organism gave the Strauss reaction with guinea pigs and agglutinated known cultures of the *Bacillus mallei.* An autogenous vaccine was made from the patient's own organism. He recovered after an illness of five months, and when last heard from had remained well. He had worked along shore previous to his illness, but had not been especially in contact with horses. Every effort was made to trace the source of his contagion but without success. One thing was certain—he had glanders.

This case is mentioned, not only on account of its interest because of the therapeutic success attending treatment, but also because it emphasizes in a particularly striking manner the necessity and the value of bacteriological work in connection with the infections. Had it not been for the friendly aid of the Hoagland Laboratory this man would have been treated as an ordinary case of metastatic abscess and many persons placed in great danger. With the possible exception of the bacillus of pest there is no organism which has claimed so many laboratory victims as *Bacillus mallei.* True, we ought always to exercise the greatest precautions in treating all infections, but when the treatment extends over weeks and daily dressings are required, vigilance is too often relaxed,

with results which are unpleasant with ordinary infections, but which might be deadly with so terrible an infection as that of glanders.

During the fall of 1910 the Directors of the Hoagland Laboratory offered to put at the disposal of the Long Island College Hospital the services of Mr. H. W. Lyall for bacteriological research into the origin of all surgical infections treated in the hospital. This offer was gladly accepted, and the cases here analyzed were those which came under the charge of the writer the past winter, together with a few others from the other operations in the hospital. A number of times Mr. Lyall went with the writer to the Kings County Hospital for similar investigations, and a few cases from that hospital are included in this report. The period of observation has been too short and the cases too few yet for our records to be more than suggestive. If attention is called to the great importance of this work so that it becomes a part of the hospital routine, which is not at present the case, the writer will feel that something has been accomplished.

BACTERIOLOGICAL ROUTINE.

Collecting of Material.—The following rules were observed:

(*a.*) Apply no germicides to an open lesion, or if such substances have been applied wash with sterile water and wait at least two hours before taking specimen.

(*b.*) Avoid contamination either from the person of the operator, instruments and supplies, the patient, or his environment.

(*c.*) Discard the first or top pus. Take the specimen from the depths of the lesion, thus avoiding dead or attenuated organisms.

(*d.*) Make inoculating smears upon the surface of at least two Löffler blood-serum slants.

(*e.*) Avoid exposing the cultured material to extremes of heat or cold and delay in incubator.

(*f.*) Make at least two smears upon glass slides and fix by gentle heating.

The only addition to these procedures is in the case of lesions whose cause is known or suspected to be a very delicate organism, *i.e.*, influenza bacillus, gonococcus, etc., when media richer in animal proteid is supplied, such as blood or ascitic agar.

Laboratory Procedure.—When the specimen reaches the laboratory it goes through the following routine:

(*a.*) Stains—Gram's method and with Löffler's alkaline blue and in certain cases an acid fast stain. This serves as an inventory and an attempt is made to recover from the plates all organisms thus demonstrated in the exudate.

(*b.*) Plates are prepared of suitable media, the usual one glycerin agar. The laboratory custom in plating is the use of the ordinary streak or the Conradi method.

(*c.*) Incubation of the plated material at incubator (37.5° C.) and at room temperature.

(*d.*) Under certain circumstances anaërobic conditions are supplied.

(*e.*) Study of and fixings from the colonies developed on the plates and isolation in pure culture.

(*f.*) Identification of species by the use of differential media, animal inoculation, and immunity reactions. Blood cultures are made through an incision of the properly sterilized skin over the median basilic vein. The blood is either immediately placed into the culture medium or first introduced into an isotonic and decalcifying solution. The latter method is used if culture material is not available at the bedside. For inoculation, 5 c.c. of blood are placed into at least 100 c.c. of fluid medium and the remaining 5 c.c. of blood are distributed in plates. The fluid medium most used is neutral broth. Under certain conditions dextrose broth, lactose bile, ascitic broth, and neutral broth to which calcium carbonate has been added are used. The plate medium ordinarily used is plain agar to which may be added ascitic fluid or other enriching material.

During the winter there were 108 cases of infection examined for the writer at the Hoagland Laboratory. The cases of ruptured appendix were not here included, some thirty in number, as the resulting cultures were so rich in intestinal flora that conclusions as to the infection were not of much value. Intestinal or sewage streptococci were quite common. The colon bacillus was invariably found, not often in pure culture. The first place among the flora of the intestine in appendical infections must always be given to the colon group. It occurred in over 90 per cent. of the cases. After that, to the streptococcus. We know little as yet about the varieties of the streptococci. There is one variety, however, the individual cocci rather small and clear cut, occurring in chains of five or six members and deeply stained, which is always associated with a virulent infection. Shorter chains of four or five members, the individual cocci rather large, have never been observed as associated with the

severe types of inflammation. The 108 cases which we analyzed have been classified according to the infecting organism, and occurred as follows:

Staphylococcus aureus, pure culture	25
Staphylococcus aureus, mixed	18
Streptococcus pyogenes, pure culture	22
Streptococcus pyogenes, mixed	13
Staphylococcus albus, mixed	6
Colon, pure (not including appendix cases)	11
Colon, mixed	1
Pneumococcus, pure	11
B. Friedlander, mixed	2
Pyocyaneus, pure	1
Pyocyaneus, mixed	3
Diphtheroid, pure	1
Diphtheroid, mixed	22

The appearance of a bacillus closely resembling the Klebs-Löffler bacillus so frequently in 22 per cent. of the cases is perhaps the most interesting observation in this short series of cases. It occurred once in pure culture in a granulating sinus of the thigh, following an operation for necrosis; twelve times in association with the *Staphylococcus aureus;* twice with *Staphylococcus albus,* both times in acne cases; once in conjunction with the *Streptococcus pyogenes* and *aureus;* once with *Bacillus coli* and a sewage streptococcus. It also occurred in the medical wards with mild cases of sore throat not accompanied by exudate or any serious constitutional disturbances. One case is typical of all, as follows:

J. F. recovered from typhoid fever, complained of sore throat. No exudate. Cultures from swab could not be distinguished from true Klebs-Löffler bacilli. Neisser granules found. Not pathogenic to animals. Guinea-pig inoculated intraperitoneally after an interval of two weeks in good health; autopsied; adrenals clear; no adhesions; everything normal. This man was quarantined for two months by the board of

health. During this interval he had no sore throat. This mild sore throat appeared in five post-typhoidal cases all in the same ward. In no case was the culture to be distinguished from the true Klebs-Löffler, neither was it considered to be a non-virulent diphtheria organism. Occurring in twenty-two cases of mixed infection it cannot be said, so far as was known, to have added to the severity of the case. It was most frequently associated with aureus (12 cases), next in frequency with the streptococcus (5 cases). Dr. C. F. Garside of the Hoagland Laboratory writes as follows concerning the classification of this organism:

Pseudodiphtheria Organisms.—The following tentative classification of the diphtheria and diphtheria-like organisms has been adopted by the laboratory:

1. True, virulent Klebs-Löffler bacilli.
2. Avirulent Klebs-Löffler bacilli.
3. Hofmann's pseudodiphtheria bacillus.
4. *Bacillus xerosis.*
5. Diphtheroids: Organisms which resemble the true diphtheria bacillus in the following essential features: gram positive, non-motile, non-sporulating bacilli which show a parallelism in their arrangement in smeared preparations and which fail to take the alkaline methylene blue stain in one or more areas of their protoplasm, *i. e.*, beading or barring. These organisms differ from types Nos. 3 and 4 in their sugar reactions. Diphtheroids may be divided into the virulent and the avirulent. The methods used for differentiating these classes are, first, pathogenicity to guinea pigs, and, second, fementative reactions upon various sugars.

1. Animal pathogenicity: The avirulent Klebs-Löffler bacillus can be differentiated from the avirulent diphtheria-like organisms by its reaction on carbohydrates, notably its ability to ferment dextrin. The virulent true Klebs-Löffler bacillus can be separated from the virulent diphtheroids by animal inoculation, first protecting the experimental animal by immunizing it with diphtheria antitoxin, or by mixing the inoculating dose with diphtheria antitoxin. In either case the animal will survive inoculation with diphtheria bacilli, but will not be protected from the virulent diphtheria-like bacilli.

2. Fermentative reactions: Under ideal conditions distinct differences are brought out by this method, but certain variations in the reactions of the same strains, because of varied conditions, little understood and difficult to control, have cast some doubt upon the advisability of accepting such evidence as final. Consequently we rely upon the evidence supplied by animal inoculation of differentiation between the true Klebs-Löffler bacillus and its allied forms. For the present, the classification of the diphtheria-like organisms and the avirulent true Klebs-Löffler bacillus is based on their fermentative reactions and their cultural characteristics.

The importance of making the distinction between true Klebs-Löffler bacilli and the diphtheroid group cannot be overestimated. A hospital staff could easily get panic-stricken if the diphtheroids were not differentiated as indicated. In the absence of the clinical signs of diphtheria it is evident that the ordinary board of health methods will not avail, nor the presence of the Neisser granules, sometimes considered pathognomonic, be at all conclusive. The only trustworthy methods of differentiation are the behavior of the two organisms with the sugars, plus animal inoculation.

Four of the post-typhoid cases having diphtheroids in the throat were isolated and given special nurses, also isolated, for long periods of time, far longer than was necessary to determine the exact nature of the organism. The hospital and boards of health must always err on the safe side. At the same time we ought to recognize the fact that diphtheroids do exist which are non-pathogenic and, so far as known, without influence on wounds. The single case in which a pure culture of diphtheroid was isolated from a granulating sinus recovered without any untoward symptom. Further observations on the behavior of this organism in wounds and its influence thereon are most desirable.

The number of closed infections with pure cultures of aureus, streptococcus, pneumococcus, and colon bacillus was of great interest. It was impossible to trace the path of the infection in any of the cases, as they were all seen late in the course of the affection when a definite abscess had developed, and it was not possible to discover the origin, whether hæmatogenetic or by the lymphatic paths from mouth, tonsil, or the intestinal tract.

The following cases of aureus infection were not preceded by abrasion or wound. From a subdiaphragmatic abscess a pure culture of aureus was obtained. No history of ulcer of the stomach obtainable; no pleurisy. Six cases of prepatellar bursitis were treated and cultured. Like the carbuncles of the neck, of which there were five, from all a pure culture of aureus was obtained. One of the cases of prepatellar bursitis was opened

early before sinus formation. The swelling was of two weeks' standing. There was no abrasion of the skin. Pure aureus was obtained from the abscess cavity when opened. A case of osteomyelitis of the lower end of the tibia in a child of twelve years, of unhealthy appearance, had been preceded by several aggravated furuncles of the face. Cultures obtained from the bone abscess when opened proved to be aureus. The furuncles had healed at this time and could not be cultured. Many cases of osteomyelitis are said to be preceded by tonsillitis. It is evident that in all these cases of osteomyelitis the infection must be by the blood stream and not against the lymphatic current by way of the lymphatics. A second case of osteomyelitis, a Brodie's abscess, was as follows:

A young woman of twenty-five years, domestic, came under the writer's care suffering from pain in the lower portion of the left tibia and a temperature range of 100°–102°. Eight years previous she had suffered from an osteomyelitis of the same tibia, which had been operated. After recovery the intervening years had been free from illness until two weeks before writer saw her. The Röntgen ray showed a shadow at the lower end of the tibia about four inches from the malleolus. On cutting down on this spot the bone percussion note was dull, and, on trephining, a well walled off abscess cavity was found, cultures from which, made from the interior of the bone cavity, proved to be mixed, albus and streptococci in long chains. The cavity was filled with bone wax and the patient made a good recovery.

It is difficult to trace the infection in this case or to see why albus, which is a skin organism, should have gotten into a closed bone abscess in conjunction with a streptococcus infection. Moreover, this is the only case in which a closed abscess gave a mixed infection. It is possible for these organisms to have remained in the bone, from time of the first operation, but it does not seem likely in view of the rather delicate nature of both organisms. Aureus has been known to remain viable for years, but so far as the writer knows, not albus nor the streptococcus group, which die rather easily. Three aureus abscesses of unknown origin were opened. One of these was inguinal, no injury, no

urethritis; swelling of two weeks' duration drained; culture, aureus. A second abscess, subfascial, not associated with sore throat nor tonsillitis, was opened at the angle of the jaw and proved to be also aureus. There was no carious bone nor dental caries in connection with this case. The proximity to the mouth suggests a lymphatic course for the infection.

A most interesting case was as follows:

The writer saw in consultation a man fifty-seven years of age with the following history: He had been treated for two weeks by his brother, a physician, for grippe. He had a chill, fever to 103°, malaria. Later pain in the right wrist, some swelling, then pain in the region of the right hip, œdema, swelling. An exploring syringe revealed the presence of an abscess under the fascia lata, which was drained, cultured, and proved to be pure aureus. It is difficult to trace the origin of this infection. The patient made a good recovery and never showed any evidence of infection elsewhere. The affected wrist suggests a hæmatogenetic origin, but it was not possible to say that there had been an endocarditis, and in view of the extremely fatal character of endocardial infection of the aureus type, the inference is that no endocarditis had preceded the attack.

A somewhat similar case to this treated by the writer occurred in the person of a lady, who for three weeks previous to her coming under the care of the writer, had recurrent attacks of what was diagnosed as Pfeiffer's glandular fever. The attack had also been called grippe. Each of the weekly attacks had been preceded by chill, fever, malaria; the last by some swelling in the neck anterior to the left sternomastoid muscle. This finally proved to be an abscess underneath the deep fascia of the neck and was drained. A streptococcus was cultured from the pus, but was a slow grower, not showing any growth until the fifth day. This lady developed a soft murmur at the aortic orifice, developed septic wrists and knee, had three convulsions, although the urine was negative, but finally recovered after the use of a vaccine which was not autogenous but came from the organism of another patient.

Abscesses occurring in post-typhoid are usually found to contain typhoid bacilli in pure culture. This is not always the case, as the following case shows:

A patient in the fifth week of typhoid, convalescent, developed an abscess at the right wrist, an abscess of the left leg, an abscess in both arms. Cultures taken from these abscesses proved to be aureus, streptococcus, and diphtheroids. From a tubercular sinus of the neck exactly the same organisms were recovered, although the patients were in different wards and under different house officers and nurses. The streptococcus occurred in pure culture 22 times, but was by no means always of equal virulence. In one case after a pin prick, the cellulitis started in a few hours and involved the lymphatics to the shoulder in 48 hours.

One curious case of streptococcic infection was as follows:

A negro came into the writer's service in the Kings County Hospital with a swelling of the axilla and upper arm. His story was that his employer had been operated upon at home for an abscess of the arm and he had cleaned up the room after the operation. The following day he complained of pain and swelling in the right arm and came to the hospital for treatment. The hand was carefully examined for a scratch or abrasion of any kind, but none was discovered, nor was the hand affected at any time, the infection being restricted to the area above the elbow. Drainage showed a pure culture of the streptococcus. Another abscess of the axillary fossa without history of injury or abrasion showed a pure culture of streptococcus in short chains.

The most likely source of contagion in abscesses of this type and in perhaps all subcutaneous abscesses not of traumatic origin is in an infected sweat gland or hair follicle. There was no evidence in any of the cases beyond conjecture that either of these was the starting point of the infection.

Two cases of streptococcic infection occurred in fractures. The first was in the writer's service at St. John's Hospital and was subsequent to the application of a Lane plate for bad oblique over-riding fracture of tibia and fibula, with great displacement. The writer has used the Lane plate in nine cases during the past

winter with good results, except in this case, which he relates in order that it may at least serve as a warning against the indiscriminate use of the open method in this treatment of fractures. The subject of the fracture was a young man of alcoholic habits, who received the injury as a result of an automobile accident. The case was ideal for the open method, as the bones, when reduced could not be held but slid past each other with much over-riding. The operative field was most carefully prepared twice after the usual method. After the patient was in the operating room, the leg was painted with tincture of iodine, which was allowed to dry. Every one connected with the operation wore rubber gloves. There was very little handling of the tibia to which the Lane plate was secured, resulting in perfect apposition. The fascial wound was closed with catgut, the skin with silkworm gut, a dressing applied and a plaster case. The wound showed evidence of infection on the second day and a window was cut in the case, the sutures removed, and pus found which was of streptococcus origin. Every effort was made to trace the error in technic if any. The gauze, the suture and ligature material were tested and the samples taken shown to be sterile. The nasal cavities of every one concerned in the operation were cultured and no streptococci found. There was not another streptococcus case in the hospital, and the writer went straight from the operating room of this hospital to another hospital and did three operations, one a gastro-enterostomy, all of which recovered with primary union. Drs. Avery and Garside of the Hoagland Laboratory made every effort to hunt down the source of contagion but failed. The patient ran the gauntlet of prolonged suppuration, multiple incisions, necrosis, and is now, five months after the operation, just beginning to get union. Was the source of this infection hæmatogenetic? In view of the many cases of closed infection which occurred in this series without the intervention of any injury, we cannot absolutely deny the possibility that an operation wound may become infected from within and not from without.

The other streptococcus infection occurred secondarily in a compound fracture of the tibia, which had been wired at the Coney Island Hospital. Three months afterward the attending surgeon did an operation for the removal of some necrosed

bone. This was followed by a rise in temperature and evidences of severe infection. The writer saw the case the week after the operation for necrosis, and on examining the patient's heart found a soft blowing murmur. Diagnosis, septic endocarditis, probably of streptococcic origin. Blood culture showed 100 colonies of streptococci to the cubic centimetre. In spite of treatment by vaccines and antistreptococcic serum this patient died. No cultures were taken from the wound prior to the second operation. The writer desires to make the point that this should have been done, and immunizing doses of the organism found and given prior to the second operation. It is evident that a bacteriological examination of the old wound prior to operation might have served to put the surgeon on his guard and might have avoided a catastrophe.

Seven cases of puerperal infection occurred in this series of cases, of which four were of pure streptococcic origin. In these four cases blood cultures were taken and streptococci recovered as follows:

A. T., January 12. Induced abortion; culture shows long chain streptococci, 200 colonies in 0.5 c.c. of blood; death.

Mrs. E., puerperal sepsis eighth day; blood culture; streptococci in long chains; 12 colonies in 2 c.c. of blood. Culture from cervix streptococci. An autogenous vaccine was made for this case and she recovered but developed a deep abscess of the right hip, subfascial, running in the direction of the thyroid foramen. This was drained, and cultures taken proved to be streptococcic in character. Ten days after drainage she again developed an evening rise in temperature. Careful examination showed no retained pus, no abscess or evidence of inflammatory process in the pelvis. She again received an autogenous vaccine and the temperature fell to normal, after which she recovered. This is the second case of abscess of the upper thigh occurring secondary to a puerperal infection observed by the writer lately. It is possible that it is of lymphatic origin via the lymphatics which accompany the obturator artery and vein into the pelvis.

Case IV.—Induced abortion six weeks previous. Patient seen by family physician one week after the operation for abor-

tion; temperature 104°; had been told by "operator" that she had grippe. Sepsis six weeks' duration; no phlegmon. Seen then by writer. Marked endocardial murmur. Pelvis clear. Septic wrists and knees, chills; temperature 102°–104°. Blood culture showed numerous streptococci, colonies not counted. The administration of a polyvalent vaccine (Van Cott's formula) and subsequently an autogenous vaccine followed by a remission of all the symptoms. A week later, however, patient embolized her left middle cerebral and also developed septic infarcts in both lungs and died.

The three cases of mixed infection were as follows:

Peritonitis following abortion. Death. Swabs from peritoneal cavity at autopsy showed streptococci of the large variety, the chains occurring end to end, probably the intestinal streptococci and diphtheroids developing in a very delicate growth on the culture medium.

CASE II.—Mixed infection, puerperal sepsis following delivery by students. *Staphylococcus aureus, albus,* and *Streptococcus longus.* Recovery.

CASE III.—Sepsis following delivery; brought to the hospital. No blood culture; vaginal swab showed colon and albus. Recovery.

Of these seven cases all were streptococcic in type except one in which only colon and albus were found. This was of mild type. Six of the cases were induced abortion.

The pneumococcus in pure culture was usually found in the empyemas, when there was an intercurrent or preceding pneumonia. There were four cases of special interest of pneumococcus infection in cases not empyema.

CASE I.—A. B., Kings County Hospital. Dry pleurisy, right side, followed by a painful swelling at the region of the right sternoclavicular joint which appeared quite rapidly. Pus from the drainage operation showed a pure culture of the pneumococcus.

CASE II.—Pneumococcus infection of the right knee-joint. This was a man in the Kings County Hospital who came into the service after an illness of two weeks. His account was that the right knee became swollen and painful after a fall

which did not bruise the knee or break the skin. Patient thought he had rheumatism. Examination showed a much swollen knee-joint full of fluid; temperature 101°–104°. Aspiration proved the contained fluid to be pus. Culture showed a pure pneumococcic infection; no pneumonia; no pleurisy. The Mayo operation done for drainage. Pus found to have escaped from the capsule into the intermuscular planes. Attempts to save the limb in vain and patient died.

CASE III.—Compound fracture of the head of the humerus in a stout woman of forty-eight years, Kings County Hospital. Wound enlarged; head and shaft joined by Lane plate. Infection, pneumococcus, drainage. This patient did well for a time, but the arm was subsequently removed at the shoulder for a renewal of the infection by the writer's successor in the service.

CASE IV.—Pneumococcic conjunctivitis, contracted from patient's daughter and when first seen was thought to be of gonorrhœal origin. Cultures showed a pure pneumococcic infection.

All the cases of suppuration in which the pneumococcus was found were of a severe type. The empyemas were classified as follows: those following pneumonias, in all but one of which pure cultures of the pneumococcus were found. In one case, that of a child who came to the hospital with fluid in the right chest, a bronchopneumonia had been present and the cultures from the drainage operation showed aureus and diphtheroids, the former predominating. An empyema said to have followed an attack of influenza was aspirated, but cultures from the aspirated fluid, though this was turbid, remained sterile. Resection of a rib was done for free drainage. Cultures from the drains gave a Gram negative bacillus which proved to be Friedlander. This patient died. The drained fluid was thin and bloody.

An interesting case of encysted empyema was that of a patient, a man fifty years of age, with cough and expectoration suggesting tuberculosis. No tubercle bacilli, however, were ever found in his sputum though frequently sought for, but numerous streptococci. The Von Pirquet reaction was negative.

He developed an encysted pleurisy just posterior to the angle of the scapula, which was drained. Cultures taken from the drainage showed pure streptococci. Although perfectly free drainage had been provided, patient continued to run an evening temperature. Finally he received a vaccine made from his own organism, after which his temperature fell to normal.

Five cases of perinephritic abscess came under the writer's observation and were drained. Four of these were pure aureus, one a colon infection. On the contrary all of five cases of unilateral hæmatogenous infection of the kidney showed pure cultures of the colon bacillus, the cultures being taken from the small abscesses in the renal cortex after hemisection of the kidney, subsequent to the nephrectomy. No deductions can be drawn from a few cases, but one would naturally expect perinephric abscesses to be the result of colon infection rather than aureus, owing to the proximity of the colon. In the infected kidneys, the origin was clearly hæmatogenetic, as the abscesses occupied the location of the vascular tufts. This variety of infection is probably never the result of an ascending infection of the bladder, the symptoms being quite different from and far more severe than a simple pyelitis or even a pyelonephritis.

This short collection of cases is submitted with much diffidence. Yet few in number as are the cases, the labor involved in the isolation of the infecting organisms has been very great and has consumed much time. It is the intention of the writer to continue the work with the assistance and collaboration of the Hoagland Laboratory. In course of time it may be possible to make conclusions of value. It is not impossible that we may find a method of immunizing a patient against infection previous to operation or to sterilize the blood current and tissues after infection has occurred. That is what Ehrlich has done in syphilis.

The writer gratefully acknowledges the assistance of Drs. White, Avery, Garside, and Mr. A. W. Lyall, the bacteriologist to the Long Island College Hospital, without whose aid this work would have been impossible.

THE ANATOMY OF SPINAL PUNCTURE WITH SOME CONSIDERATIONS ON TECHNIC AND PARALYTIC SEQUELS.*

BY WILLIAM C. LUSK, M.D.,
OF NEW YORK,
Assistant Visiting Surgeon to St. Vincent's Hospital.

(Anatomical research through the courtesy of the New York University and Bellevue Hospital Medical College.)

THE topic includes a consideration of the propriety of tapping the spinal arachnoid sac in any region of the cord below the midcervical. For emphasis, *the conclusion from these studies is stated at the very start,* that the only vertebral interspaces through which puncture of the subarachnoid space can be made with practical assurance that nerve structure will not be penetrated, are the fourth lumbar and the lumbosacral, preferably the former. This statement presupposes the employment of a correct technic.

Key and Retzius [1] in 1828 published extensive studies of the subarachnoid space. They injected the subarachnoid space with a blue color fluid and then made frozen sections of the cord. They state that the anterior subarachnoid space of the cord is entirely free and open, but that the posterior space in the dorsal region is divided up by interrupting membranes attached in the lines of the nerve-roots. Their only suggestion of an adhesion between the posterior surface of the cord and the arachnoid membrane is contained in the following words: "At the lowest part of the cord the conditions change essentially. The posterior septum, if we include under this name the posterior arachnoid midmembrane and trabeculæ, is usually very richly developed and contains a number of larger and smaller subarachnoid spaces, at times breaking up into a thick trabecular network which occupies a large portion of, indeed almost the whole, space behind the cord between the nerve-roots" (Key and Retzius, i, p. 91).

* Read before the New York Surgical Society, April 26, 1911.

They describe a constant valve-like flap in the upper part of the anterior subarachnoid space between the levels of the second attachment of the ligamentum denticulatum and the fourth cervical nerves, convex upward, which permits a free flow of cerebrospinal fluid from brain to cord in front of the ligamentum denticulatum, but obstructs the free passage of cerebrospinal fluid from cord to brain, within this area. Propping [2] has proposed that the opening and closing of this valve with the falling and rising respectively of the spinal fluid, occasioned by the respiratory movements, by alternating a greater opening for ingress of cerebral fluid to the spinal subarachnoid space, with a smaller opening for egress of the spinal fluid to the cranial subarachnoid space, were causative of an active circulation between cranial and spinal subarachnoid fluids.

Quincke,[3] and Gerstenberg and Hein [4] have made original anatomical studies of the spinal cord. Quincke describes the close contact of the spinal arachnoid with the dura surrounding it, as analogous to the relation between adjacent pleural or peritoneal surfaces. He describes the cauda equina as divided into two lateral halves separated by a mesial cleft from 2 to 5 mm. in width. This corresponds to the variety of distribution of the nerve-roots of the cauda equina found in Dissection C of this article. The conus medullaris in very young children lies lower than in adults. Quincke says in this regard: "In eight cadavers of children up to one year of age I found the end of the conus at the level of the third lumbar vertebra, in children three years old at the level of the second lumbar vertebra—only once in a four-year-old child at the level of the fourth lumbar vertebra."

Gerstenberg and Hein state that the position of the nerve-roots of the cauda equina in the subarachnoid space is variable, sometimes the roots lying close to the posterior and lateral walls and again nearer the anterior wall. They give as the usual condition, that in which the nerve-roots divide into two lateral halves, leaving the anterior wall of the space free. They describe the subarachnoid space of the spinal region above the cauda equina as divided by the garland-shaped ligamentum denticulatum into an anterior portion and a pos-

terior portion, the two portions communicating with each other through the spaces between the concavities of the ligamentum denticulatum and the arachnoid sac. Also they note the presence in this space of a posterior median septum in which are holes affording communication between the two sides. These authors have described the extradural veins within the spinal canal. Venous arcades cross the posterior surface of the dura, underlying the bony arches, so that the main vascular channels posteriorly are out of the line of puncture. Anteriorly these veins, which lie on the posterior surfaces of the bodies of the vertebræ, are much larger and more numerous than the posterior ones. With their condition of distention or of collapse the content of cerebrospinal fluid in the subarachnoid space is regarded to vary.

Magendie [5] connected a tube with an animal's subarachnoid space and saw the cerebrospinal fluid rise and fall in the tube synchronous with the movements of respiration.

Propping brings out the fact that the fat at the intervertebral foramina, which is displaceable, and the peridural veins accommodate the changes of intradural pressure.

The writer has observed that the sizable anterior extradural veins of the lumbar region, which are mesially situated, occupy exclusively the transverse hollows on the posterior surfaces of the bodies of the vertebræ between the projecting upper and lower bony margins, and are separated from the dura by the posterior common ligament of the spine, which bridges over the hollows. Between these transverse hollows, in the mesial area of the spine, the intervertebral disks, together with the lipped margins of the adjacent vertebræ above and below, form projecting surfaces measuring about three-fourths of an inch in a vertical direction, which act as piers to support the posterior common ligament, over which areas there are no sizable vessels. Only over the lateral portions of the posterior surfaces of the bodies of the lumbar vertebræ, just within the line of the intervertebral foramina, do the venous plexuses pass upward and downward in the vertical direction. This anatomy has the following surgical importance: that, since the intervertebral disks are situated in the line of a straight forward puncture between two ad-

jacent lumbar spinous processes, with a mesially directed puncture it would hardly be possible for the most inadvertent operator to pierce any of the anteriorly lying extradural vessels.

The writer presents in this paper his findings in fifteen dissections of the spinal cord, in all of which the anatomy of the cauda equina was studied, and in eleven the portion of the arachnoid membrane in relation with the posterior surface of the cord from the conus medullaris up into the cervical region was carefully dissected.

With the exception of the diagrammatic cross sections, the illustrations in this article are either photographs or drawings from photographs.

Especial pains have been taken to demonstrate by these illustrations the varying relations of the arachnoid membrane to the nerve structures, which relations are all-important in establishing a site of greatest safety for tapping the subarachnoid space. Thus localities where the posteriorly lying arachnoid was found adherent to the surface of the cord or to an agglutinated mass of nerve-roots of the cauda equina, would manifestly be unsuitable for puncture.

The writer has located the upper borders of the lumbar pedicles (and the intervertebral disks immediately above them) as corresponding to the levels of the intervals between the posterior extremities of the spinous processes, so that in studying the illustrations, the sites of entrance into the spinal theca of a needle introduced through different lumbar interspaces can be estimated from the situation of the pedicles.

PUNCTURE AT AND ABOVE THE LEVEL OF THE CONUS MEDULLARIS (Figs. 1 and 2).

The anatomical findings in the eleven dissections of the arachnoid membrane, from the conus medullaris up into the cervical region, were condemnatory to the procedure of puncture within this area, as one attended with the greatest liability of penetrating the cord.

In the whole 15 dissections, the conus medullaris was 11 times found at the level of the first lumbar vertebra, 3 times

at the level of the junction between the twelfth dorsal and first lumbar vertebræ, and once reached to the lower border of the second lumbar vertebra.

Of the eleven dissections of the arachnoid membrane above the conus, in but three—which included Dissections F (Figs. 14 and 15) and G (Figs. 16 and 17)—was there a complete posterior arachnoid space present all the way up into the cervical region. In all of these three there were at intervals interrupting transverse septa, so that the channel posteriorly was not continuous. However, its lateral com-

FIG. 1.

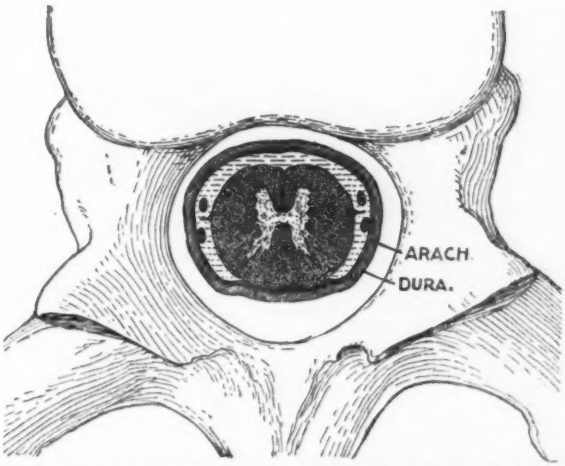


Diagram of a cross section through the dorsal spine, showing how the arachnoid membrane may be adherent to the posterior surface of the cord, which was the predominating anatomical arrangement in this and the lower cervical regions in six out of ten dissections. The close contact between the arachnoid and dura is here illustrated.

munications with the anterior portion of the subarachnoid space over the concavities of the ligamentum denticulatum provided opportunity for a free circulation of the cerebrospinal fluid. In a fourth dissection the posterior arachnoid space was present throughout, excepting for an adhesion of the arachnoid membrane to the cord for an interval of about half an inch opposite the first dorsal vertebra. It, as well, was partitioned by the usual interrupting septa in other situations. In three dissections (including D, Fig. 12, and E, Fig. 13), the arachnoid membrane was adherent to the pos-

terior surface of the cord all the way from the conus up into the cervical region. In one dissection the arachnoid membrane was completely adherent to the posterior surface of the cord above the level of two inches above the conus, in another, above the level of three inches above the conus, and in two others, above the levels of the fifth and seventh dorsal vertebræ respectively. In the last mentioned case the arachnoid membrane was likewise adherent over the anterior surface of the cord from the level of the ninth dorsal vertebra upward into

FIG. 2.

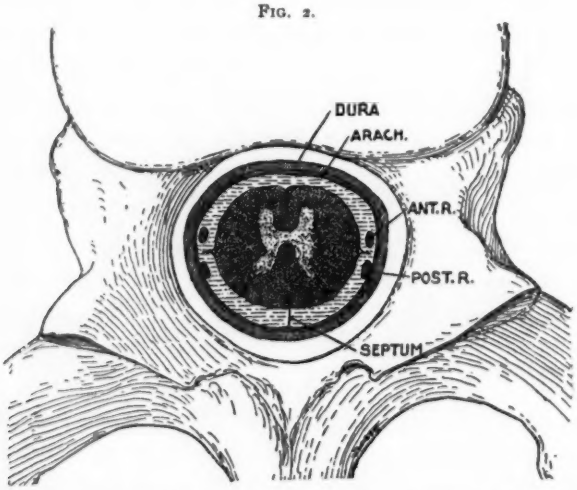


Diagram of a cross section through the dorsal spine, showing how the subarachnoid space may completely surround the cord. An anatomical arrangement of the posterior part of the arachnoid sac, like that here pictured, was found to exist throughout both dorsal and cervical regions in but three out of eleven dissections, and in these the continuity of this posterior part of the channel was interrupted at intervals by transversely lying septa. There is free communication between the anterior and posterior portions of the subarachnoid space through the openings between the concavities of the ligamentum denticulatum and the arachnoid sac. ANT. R., POST R., nerve-roots.

the cervical region. Laterally in this case, however, the subarachnoid space was open.

The *conclusion* is that if cerebrospinal fluid can be constantly drawn as a result of mesial puncture at or above the level of the conus, in many instances the substance of the cord must be traversed by the needle and the fluid taken from the anterior portion of the subarachnoid space.

Illustrative of the danger of perforating the cord in tapping the subarachnoid space through the dorsolumbar inter-

space, were the findings in Dissections D and E. In each of these cases, the conus terminated opposite the first lumbar vertebra and there was an adhesion of the arachnoid membrane over its posterior surface. In another one of the dissections, in which the tip of the conus was at the level of the disk between the twelfth dorsal and first lumbar vertebræ, the lumbar arachnoid sac extending free posteriorly only up to the V-shaped outline of the conus, and above becoming adherent to the cord, it would seem quite certain that here, too, to have drawn cerebrospinal fluid as a result of tapping in the dorsolumbar interspace, the needle, which would have been directed about opposite to the tip of the conus, would have had to have penetrated through the nerve structure into the anterior subarachnoid area. In each of eight other of the dissections in which the relations of the arachnoid membrane to the posterior surface of the cord opposite the dorsolumbar interspace were investigated, there was found present in this locality a freely open subarachnoid space, so that in these cases it would have been possible to have punctured the arachnoid sac through this interarcual interval, without injury to the cord.

It is of importance in this connection to consider the work of Rehn,[6] who injected physiological doses of tropacocaine, novocaine, and stovaine into the spinal cords of animals, causing immediate death with typical medullary symptoms. This result occurred regularly, even with diminishing the doses of the drugs to very small amounts. To test whether the effect of these injections was mechanical or toxic, physiological salt solution alone was injected into the spinal cords of animals without any recognizable effects.

A review of some of the cases in which sudden death has occurred soon after the injection of a spinal anæsthetic would embellish this trend of thought.

Especially pertinent are those cases in which the puncture was made in the dorsolumbar interspace. Such cases are, however, few, owing to an almost general obedience to Quincke's precept early laid down, that spinal puncture should be made only below the level of the conus medullaris. Also

of interest in this connection are deaths under spinal anæsthesia, for which definite pathological lesions were found at autopsy to have been accountable.

Cases associated with high pelvic elevation, in which, probably from the heavy specific gravity of the solution used, or from a shifting of the spinal fluid cranialwards, the respiration has become paralyzed beyond the power of restoration, have been here omitted as irrelevant.

Fatalities During Operations Under Spinal Anæsthesia, Other than Cases of Respiratory Paralysis Associated with High Pelvic Elevation.

(*a*) *Where dorsolumbar puncture had been made.*

MILWARD (F. VICTOR): *Death under spinal anæsthesia by Jonnesco's method in a case of acute intestinal obstruction. British Medical Journal, March 26, 1910, p. 743.*

Intestinal obstruction. Injection of 10 cg. of stovaine and 1 mg. of strychnine in 1 c.c. of water between the eleventh and twelfth dorsal vertebræ. Head raised on a thick pillow. In 7 minutes the pupils were dilating and the pulse commenced to fail. Vomited. In 10 minutes patient quite unconscious—gasping respiration and profuse vomiting. In 12 minutes the pulse was imperceptible and the respirations had ceased. Autopsy: The blood-vessels of the surface of the cord over the lumbar enlargement were engorged. The cord appeared not to have been touched by the needle and macroscopically its structure was normal. No hemorrhage observed inside the spinal theca.

GABBETT: *British Medical Journal, March 26, 1910, p. 690.*

Age 40. Elephantiasis of scrotum. Puncture between the twelfth dorsal and first lumbar vertebræ, from which the spinal fluid flowed freely. Ten cg. of novocaine and 1 mg. of strychnine hydrochloride injected. The patient sat up for 1 minute and then laid down with his head on a low pillow. In 5 minutes he was anæsthetic to the level of the nipples and in 10 minutes almost to the level of the clavicles. The patient died of respiratory failure within half an hour.

(*b*) *Where death was due to a cause other than the spinal anæsthetic.*

BONDY: *Ueber das post-operative Verhalten nach Lumbal-anæsthesia. Gyn. Rundschau, iv, 1910, p. 99.*

The patient had a systolic murmur with a striking cyanosis of the face. Five minutes after the injection before the elevation of the pelvis the patient died. Autopsy: embolus left pulmonary artery.

HOHMEIER: *Hohmeier u. König. Verhandl. d. deuts. Ges. f. Chir., xxxix, 1910, p. 481. Sammelforschung über die Lumbalanæsthesie im Jahre 1909.*

In a collection of 2400 cases from 41 institutions in the year 1909, there was one patient suffering from arteriosclerosis who died 10 minutes

after the injection of the spinal anæsthetic from cerebral apoplexy. There was adrenalin in the injecting fluid.

(*c*) *Other cases.*

DÖNITZ: *Wie vermeidet man Misserfolge bei der Lumbalanæs. Münch. med. Wchsft., 1906, p. 1338.*

The following was the first case of death caused by the anæsthetic in more than 1000 cases of lumbar anæsthesia in Bier's clinic:

Age 75. Carcinoma of penis. 0.13 g. tropacocaine diluted with 10 c.c. of spinal fluid injected between the second and third lumbar vertebræ in the sitting position. The patient was then laid flat, the anæsthetic rapidly extended to the neck, and in a few minutes the breathing and pulse stopped. Autopsy: brain and spinal cord showed nothing special. Death regarded to be due to the large dose of tropacocaine.

VEIT: *Bruns Beiträge z. kl. Chir., liii, p. 751.*

Age 63. Enlarged prostate. After having been successfully subjected to novocaine spinal anæsthesia on the sixth and third previous days, there was administered a lumbar injection of 0.07 g. stovaine. Three minutes after the injection the patient suddenly became pale and the pulse and breathing stopped. Autopsy: small hemorrhage at the site of puncture within the dural sac. No macroscopic changes in the cord throughout its entire course. Veit states elsewhere that he always punctured between the second and third or the third and fourth lumbar vertebræ.

REHN: *Ueber Rückenmarksanæs. Mitteil. a. d. Grenzgeb. der Med. u. Chir., xix, 1908–9, p. 806.*

(*a*) Quotes the results of Körte, who in 180 cases of lumbar anæsthesia had one death attributable to the anæsthetic. Woman, age 71. Incarcerated femoral hernia. Pulse 88. 0.05 g. alypin with adrenalin administered by lumbar puncture. No pelvic elevation. Forty minutes after the injection collapse and death. Autopsy: the cord was without pathological changes.

(*b*) Quotes the results of Brentano, who in 99 cases experienced one death from the anæsthetic as follows: Age 75. Irreducible umbilical hernia. 0.04 g. alypin with suprarenin injected between the second and third lumbar vertebræ. Clear fluid was first drawn. Very slight pelvic elevation. In 10 minutes the pulse and respiration became irregular and in 30 minutes the patient died. Autopsy: no cause for the sudden death.

(*c*) Reports out of 30 cases at the Charlottenberg Western Hospital, 1 death, as follows: Woman, age 79. Ileus from inoperable rectal carcinoma. Slow strong pulse. After the injection of novococaine suprarenin a small cushion was put under the hips. In 10 minutes the patient became pale and vomited and the pulse slowed. Cushion immediately removed but the patient died in another 10 minutes.

HOHMEIER U. KÖNIG: *Sammelforschung über die Lumbalanæsthesie im Jahre 1909. Verhandl. d. deuts. Ges. f. Chir., xxxix, 1910, p. 481.*

Out of 12 deaths in 2400 cases of lumbar anæsthesia collected from 41 institutions, due to the spinal anæsthetic, 4 were due to respiratory

paralysis occurring shortly after the injection. Hohmeier says: "In such cases autopsy gives no clue to the cause of death, neither macroscopic nor microscopic changes being found."

KÖNIG: *Sammelforschung über die Lumbalanæsthesie im Jahre 1909, Hohmeier u. König. Verhandl. d. deuts. Ges. f. Chir., xxxix, 1910, p. 481.*

Age 60. Intracapsular fracture of femur. Three novococaine Höchst tablets used for injection. "In 5 minutes the anæsthesia was up to the navel and in 10 minutes asphyxia supervened, and in spite of all effort to resuscitate the patient she could not be saved."

BONDY: *Ueber das post-operative Verhalten nach Lumbalanæsthesia. Gyn. Rundschau, iv, 1910, p. 99.*

(*a.*) Woman. Osteomalacia. Three days post partum. In good condition. Ten minutes after the injection stopped breathing and died. Autopsy: œdema of the brain; cystitis; pyonephritis.

(*b*) Cæsarean section. Five minutes after the injection, before raising the hips high, the patient died of respiratory paralysis. Autopsy: gave no cause for death.

Bondy had 3 deaths in 1000 cases attributable to the spinal anæsthetic.

MICHELSSON: *Ein Beitrag z. Lumbalanæsthesie mit stovain-Billon. Arch. f. kl. Chir., xcii, 1910, 657–724.*

Age 37. Pyloric stenosis. 0.056 g. stovaine. Also morphine 0.01 and scopolamine 0.0005. The horizontal posture was maintained. After 5 minutes there was satisfactory anæsthesia to the ensiform cartilage. On presenting the stomach there was sudden collapse and death.

Michelsson out of 400 cases of lumbar anæsthesia had 4 deaths attributable to the anæsthesia.

SELLHEIM: *Ueber Geschicte, Anatomie, und Technik der Rückenmarksanæsthesie. Medizinische Klinik, 1910, vi, p. 5.*

Out of 1000 cases of major gynæcological operations done under spinal anæsthesia he reports one death which could be chargeable to the anæsthetic. The case was one of proposed Cæsarean section who died before the *Kaiser schnitt* could be undertaken.

PUNCTURE BELOW THE LEVEL OF THE CONUS MEDULLARIS.

Arrangement of the Nerve-roots of the Cauda Equina.—While the distribution of the nerve-roots of the cauda equina within the arachnoid sac was found to vary considerably, their general order of arrangement with relation to one another was found to be uniform, which latter fact it can be seen would be necessarily so, in that the nerve-roots arise serially from the conus medullaris and pass downward in regular order to their fixed foramina of exit arranged in a vertical row on either side of the spinal canal. Thus the first lumbar root has the most lateral and highest origin from the conus medullaris. The root passing through the second lumbar foramen of exit takes its origin from the conus medul-

laris next below the first root, and so on down the whole series until from the apex of the conus the lowest sacral nerve-roots arise, which in natural order occupy the most mesial position of all the nerve-roots, either lying in close relationship with, or, in cases where there is a cleft, diverging a little from, the median sagittal plane. The mesial position of the lowest sacral nerve-roots would render them the most liable of any to injury in median lumbar puncture, traumatism to which could be offered in explanation of those cases of paralysis of the bladder and sphincters which have followed lumbar puncture.

Where the nerve-roots of the cauda equina lay together in masses they did not individually float free in the cerebrospinal fluid, but were bound closely together by delicate adhesions, which, though they could be broken apart with the use of almost no force at all, were nevertheless strong enough to hold the roots together as one solid impermeable structure. Occasionally the nerve-roots were found to float free but only in the lower part of the subarachnoid space, below where the main mass had been distributed. Thus the lower nerve-roots of the cauda equina in Dissection B (Fig. 7) were separate and free, as were also the nerve-roots from the lower lumbar region downward in one of the dissections of Type I not here illustrated.

The Sacral Leverage.—The sacrum, projecting posteriorly from its site of articulation with the lumbar portion of the spinal column, when forced downward has the action of a lever of the second order on resisting structures attached to its upper surface at a sufficient distance from the point of fulcrumage. The sacral nerve-roots may, under certain conditions, constitute such resisting structures in relation to the sacral lever. Thus when the subarachnoid space extends far enough downward into the sacral canal and is at the same time of sufficient calibre to allow those nerve-roots which are fixed to the projecting portion of the sacrum to have free play, and when at the same time these nerve-roots are not too slack (cf. Fig. 13) to furnish resistance to the downward forced sacrum, it can be seen that descent of the sacral lever

will make these sacral nerve-roots taut, in effecting which, owing to the posterior projection of the sacrum, the same movement will, as well, carry the nerve-roots backward out of the lumbosacral hollow into a more posterior position (cf. Figs. 6, 7, 8, and 16).

The first sacral vertebra projects but little posteriorly and that chiefly at its base, above which latter the first sacral nerve-roots diverge to go to their lateral openings, so that these nerve-roots are attached too close to the fulcrum to be much if at all influenced by the sacral leverage. The bodies of the second and third sacral vertebræ are the ones which do project markedly backward, so that when a subarachnoid space of good calibre extends down to the base of one or the other of these vertebræ, allowing more or less opportunity for free play to those nerve-roots attached to the sacrum well behind the fulcrum, then it is that these nerve-roots, if of a length shorter than that of the lumbosacral curve in the descended position of the sacral lever, will come under the latter's influence. It was found that only extreme descent of the sacral lever could make the sacral nerve-roots taut. In the erect position of the body consequently, in which the pelvis is tilted well backward, the sacral nerves would be relaxed.

The sacral lever descends with the forward tilting of the pelvis which occurs in extreme lumbar flexion, in which position, therefore, in the presence of the conditions named, the mesially lying sacral nerve-roots will become taut and be carried posteriorly (Fig. 8). Conversely, when the pelvis is tilted backward the sacral nerve-roots are relaxed, and in extreme extension of both sacrum and lumbar column as well, all the nerve-roots of the cauda equina are thrown into a state of relaxation (Fig. 9). Therefore in lumbar puncture, it would seem of the utmost importance that the posture of election should be one in which the pelvis is not allowed to tilt forward, so as to be sure of securing relaxation of the mesially lying sacral nerve-roots, on the principle that a relaxed nerve-root is less likely to become impaled upon the point of the puncturing needle than is a tense one. Also

FIG. 3

FIG. 4.

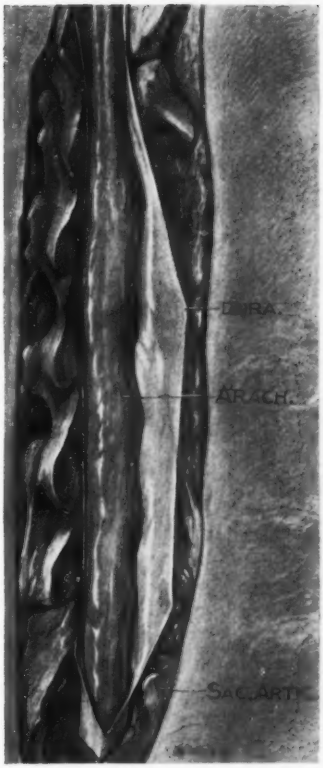


FIG. 3.—Dissection A, Type I (most frequent, 46.6 per cent.). The nerve-roots of the cauda equina, being connected together by delicate adhesions, form a flattened ribbon-like mass which occupies an anterior position in the arachnoid sac (cf. Fig. 5) and is attached on either side by the nerve-roots at their sites of exit, as well as by the adhesion of the same to the arachnoid membrane where they take a lateral position before gaining exit. In this type the positions of the sacral nerve-roots are not altered by extreme lumbar flexion (see "sacral leverage," p. 459). The delicate transparent arachnoid membrane here lay invisible, covering the nerve-roots. SAC. ARTIC., sacral articulation.

FIG. 4.—Dissection A, Type I. Shows the arachnoid membrane, unseen in Fig. 3, now inflated with air. There are no nerves in relation with its posterior aspect (cf. Fig. 5), and puncture in this case could have been made safely by a direct lateral as well as by the median route through any one of the lumbar interspaces. In contrast, see Fig. 13.

when relaxed by posture, these nerve-roots if free from arachnoid attachment are capable of taking a more anterior position in the subarachnoid space than when they are taut (Figs. 9 and 11).

Downward forcing of the sacral lever produced no tension on the sacral nerve-roots in the dissections of Type I, in which the nerve-roots of the cauda equina lay bound together in a flattened mass situated anteriorly in the subarachnoid space, nor in the Dissections E (Fig. 13) or F (Fig. 14), in which latter two the nerve-roots were of too great a length to offer any resistance to the descended sacrum. Of Type I, five of the dissections were examined to investigate the reasons for the absence of the action of the sacral leverage upon the sacral nerves, and there were found the following anatomical variations to explain the condition: in three of the cases the subarachnoid space did not extend below the level of the first sacral vertebra, which, as stated, exercises practically no leverage upon the first sacral nerve-roots, and the nerve-roots below the first sacral were bound down to the sacral bodies, so that, being consequently of a length equal to that of the lumbosacral curve they moved in unison with the sacrum, and could exercise no restraint upon its descent. In each of the two remaining dissections of Type I, the subarachnoid space extended down as far as to the lower border of the body of the second sacral vertebra, but in both the nerve-roots were evidently too long to receive the pull of the descended sacrum, and in one of these the dural sheath over the second sacral vertebra was of such small calibre as practically to simulate the anatomical arrangement where the nerve-roots over this area were bound down to the sacrum.

Classification of the Caudæ Equinæ.—The caudæ equinæ of the 15 dissections have been classified according to the variation in distribution of their nerve-roots, into five different types, the points of differentiation among which are all amply noted in the legends of the illustrations.

Type I (Figs. 3, 4, and 5) was the most frequent, it having been found 7 times in the 15 dissections, or in 46.6 per cent.

In this type the nerve-roots of the cauda equina lay massed together against the anterior wall of the arachnoid sac, and the position of the sacral nerve-roots was uninfluenced by the descent of the sacral lever. The evident reasons for the latter result have already been given (see above, "sacral-leverage"). One other dissection of the series was pre-eminently of this same type, but it presented this variation from the normal, that three aberrant nerve-roots came into relation with the posterior part of the arachnoid sac to which they were adherent. This dissection, therefore, presenting features that might lead to surgical complications similar to those that could arise in a case like that

FIG. 5.

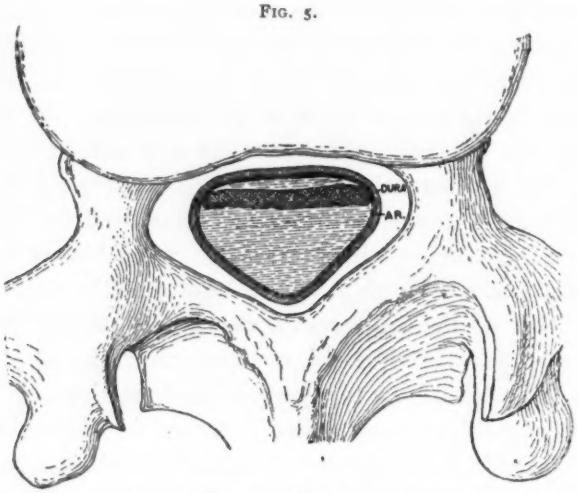


Diagram of cross section of Dissection A (Figs. 3 and 4). The nerve-roots, joined together by delicate connective tissue, lie in a flattened mass anteriorly situated in the arachnoid sac, to which latter the laterally lying nerve-roots before taking their exits are adherent.

shown in Figs. 14 and 15 (Dissection F) has been classified with the latter dissection as an example of Type IV.

In four of the dissections of this type observations were made as to the heights to which the arachnoid membranes extended upward from the lumbar sacculation free from adhesion to the posterior surfaces of the nerve structures, and it was found that once the posterior sacculation extended to the conus, once to two inches above the conus, and that in the other two cases the arachnoid membrane was for the most part free all the way up the cord excepting for the occasional transverse septal interruptions.

FIG. 6. FIG. 7.

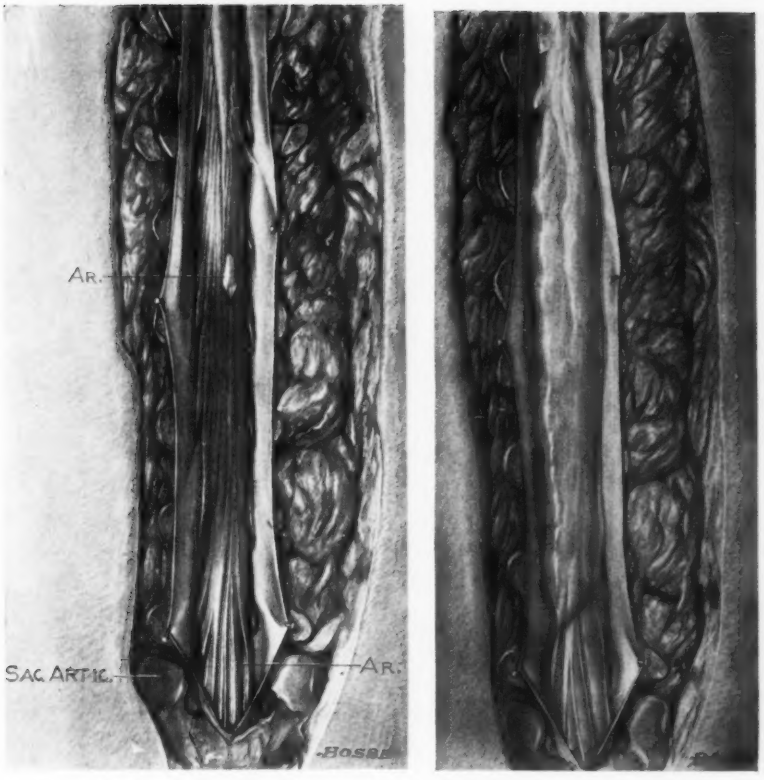


FIG. 6.—Dissection B, Type II (13.2 per cent.). This is a modification of Type I. Similar to Type I was that portion of the cauda equina above the fourth lumbar vertebra where the nerve-roots lay flat against the front of the subarachnoid space in all positions of the spine, but differing from Type I was the portion below the level of the upper edge of the fourth lumbar vertebra, where the sacral nerve-roots, by an extreme downward movement of the sacral lever, would be made taut and drawn backward so as to span the lumbosacral hollow. The subarachnoid cavity here extended downward to well over the third sacral vertebra. AR., arachnoid membrane, which is transparent, overlying the nerve-roots. Above, this membrane was lifted by an air bubble.

FIG. 7.—Dissection B, Type II. Air inflation of subarachnoid space. The air inflation could not here so certainly have reproduced the normal relation of the sacral nerve-roots to the arachnoid membrane as could have a water distention, since the close contact between these structures as here pictured was found to have been the result of a postmortem agglutination. With the introduction of water to test the fixity of the sacral roots, and at the same time raising the sacral lever to relax the same, the latter fell away from their contact with the arachnoid membrane. The sacral nerve-roots of this dissection would become relaxed in the erect position of the body.

In this type it can be seen that a straight, forward puncture into the subarachnoid space just lateral to the median line, made below the level of the conus, would encounter no nerves, yet, for the greatest safety to the patient, the needle should nevertheless be directed toward the median line, and, as well, introduced through one of the two lower spaces only, in order to anticipate the possibility of encountering an anatomical condition such as that illustrated in Fig. 13.

TYPE II (Figs. 6 and 7).—Of this type there were two specimens (13.3 per cent.). This type is a modification of Type I, the distinguishing feature being that in Type II the action of the sacral leverage on the mesially lying sacral nerve-roots raises the latter posteriorly out of the lumbosacral hollow. With sacral extension, which relaxes the sacral nerve-roots, this type practically assumes the anatomical picture of Type I. In the specimen of Type II not here illustrated, the arachnoid sac terminated opposite the middle of the second sacral vertebra, and its lower half inch was narrowed around the nerve-roots, so that, being held rather closely to the projecting portion of the sacrum, the sacral nerve-roots could come but little under the influence of the sacral leverage, and consequently the extent to which they could be raised out of the lumbosacral hollow by the action of the latter was but slight. In the same dissection, opposite the fourth lumbar interspace the mesially lying nerve-roots were connected to the posterior wall of the arachnoid sac by one-quarter inch long trabeculæ, and below this level by trabeculæ diminishing in length, until, just within the sacral canal, these roots became adherent to the arachnoid sac, which finding would seem to be in evidence of a shallowness of this lower portion of the subarachnoid space. Higher, these trabeculæ became fewer and of half-inch lengths. In this case the fourth lumbar interspace, opposite to which the trabeculæ were longer than at any level below, would manifestly have been preferable to the lumbosacral interspace for performing puncture.

TYPE III (20 per cent.) (Figs. 8 to 13) included those cases in which there was a more or less high division of the cauda equina into two lateral halves. In this type the height of the bifurcation and the relations of the arachnoid membrane to the nerve-roots presented considerable variation (Dissections C, D, and E), yielding most interesting information regarding the dangers surrounding the operation of lumbar puncture. The

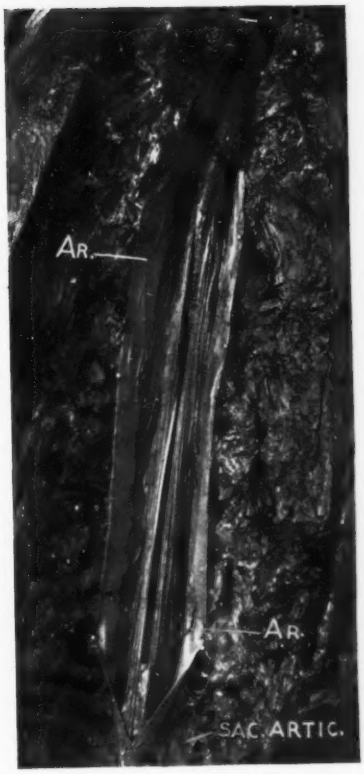
arachnoid sac in these dissections varied from a condition of complete freedom from any adhesion posteriorly to nerve-roots (Fig. 10), to one (Fig. 13) in which it was adherent to very nearly the whole posterior surface of the nerve-roots of the cauda equina, the roots in which latter case, excepting for a sizable cleft situated mesially below the level of the upper part of the fourth lumbar vertebra, formed one solid agglutinated mass. Also in the latter dissection the arachnoid membrane was attached around nearly the entire periphery of the cleft, which it bridged over, forming a window through which alone puncture into the subarachnoid space could have been effected without having to traverse the mass of nerve-roots. This dissection was the one in the series which gave emphasis to the imperativeness of a mesial entrance of the needle into the subarachnoid space in lumbar puncture, as well as demonstrated the possible danger from puncturing at a level higher than the fourth lumbar interspace.

The results of tensing and relaxing the sacral nerve-roots in this type, by descent and elevation respectively of the sacral lever, are demonstrated in the illustrations (see " sacral leverage," p. 459). Where in this type the posterior wall of the arachnoid sac is free and the subarachnoid space ample behind the nerve-roots (Fig. 10). tension on the mesially lying nerve-roots would evidently be of no import unless the needle point penetrated to the depth at which the nerves lay. Then, it can be seen that a relaxed nerve (Figs. 9 and 11) would be less liable to become impaled than would a tensed one, its mobility enabling it to elude the needle point unless pinioned by the latter against the anterior wall of the spinal canal. The relaxed nerves, with a water content of the sac, gravitated dependently from their sites of attachment, so that the positions they would assume in the subarachnoid cavity of living man would doubtless vary with the posture of the body. In the dissection shown in Fig. 13, the sacral nerve-roots were of too great length to be made taut by the descent of the sacral lever. In this dissection it can be seen that the normal fixation of the nerve mass on either side, together with the support of the sac's walls by its fluid content, must maintain the mesial position of the cleft.

The water was introduced into the subarachnoid space in the dissection illustrated in Fig. 10, through the foramen magnum.

Type IV (13.3 per cent.) (Figs. 14 and 15).—The charac-

FIG. 8.



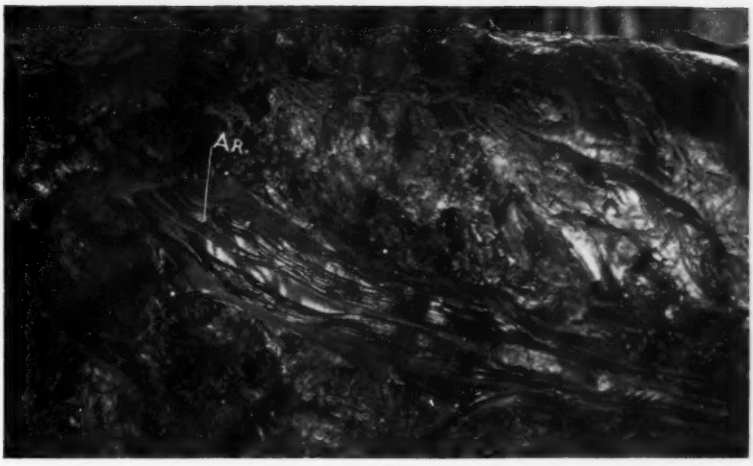
Dissection C. Type III (20 per cent.). In this type the cauda equina has a more or less high division into two lateral halves. Here the division was at the conus (cf. Figs. 12 and 13). The photograph shows the nerves made taut by the position of extreme lumbar flexion, thereby bringing into prominence the median cleft. The particular influence in making taut the mesially lying nerve-roots, which are the sacral roots, is an extreme descent of the sacral lever (see "sacral leverage," p. 459).

FIG. 9. FIG. 10.

FIG. 9.—Dissection C, Type III. Photograph showing how the nerves of the cauda equina in this dissection, seen in Fig. 8 to have been made tense in the position of extreme lumbar flexion, all became relaxed by the position of extreme lumbar extension. It is the relaxation more especially of the mesially lying sacral nerve-roots that comes up for consideration in lumbar puncture, and this can be gained simply by elevation of the sacral lever which is produced by a backward tilting of the pelvis.

FIG. 10.—Dissection C, Type III. Photograph of water distention of the arachnoid sac of this dissection. The position is that of extreme lumbar flexion, the same as in Fig. 8. Some of the nerves can be seen through the fluid in the lower part of the sac. The tensed nerves lay well away from the posterior surface of the arachnoid sac, which here looks to be more distended than it normally would have been with the support of the intact dura, showing the probable redundancy of this membrane. The fifth lumbar vertebra is *in situ*. A subarachnoid space was continued upward behind the cord from the lumbar region to a level about three inches above the apex of the conus, above which the arachnoid membrane was adherent to the posterior surface of the cord all the way up to the upper cervical region.

FIG. 11.



Dissection C, Type III. Photograph of this dissection in lumbar extension to relax the nerve-roots, the body lying on the side with hips slightly elevated. The shoulder girdle had been removed, which gave an abnormal obliquity to the dorsal spine. The picture shows in what manner relaxed nerve-roots of the cauda equina, free from arachnoid attachment, can gravitate. The higher situated half of the cauda equina hangs dependently from its site of attachment along the line of the foramina of exit of its nerve-roots, in which position it lies against the anterior surface of the arachnoid sac. The lower situated half sags into the dependent lateral curve of the arachnoid sac.

FIG. 12. FIG. 13.

FIG. 12.—Dissection D, Type III. The practical site of division of the cauda equina into two lateral halves was here originally at about the level of the second lumbar interspace, the arachnoid membrane having, before its severance, bound closely together the nerve masses of the two sides down to this level. AR indicates the lower level of adhesion of the posterior wall of the arachnoid sac to the nerve-roots, which was also the upper limit of the original cleft. Above this level, with water distention of the subarachnoid space, the nerve-roots were lifted posteriorly by the fluid, but below, the now free arachnoid sac was lifted by the water well behind the nerves. Here, puncture as low as between the second and third lumbar vertebræ would have passed through the mass of nerve-roots, but in the lower three interarcual spaces puncture could have been safely made. The position is that of extreme lumbar flexion, which here tensed the sacral nerve-roots, raising them posteriorly. With the spine upright or slightly flexed, the lateral halves of the cauda equina maintained a forward position against the anterior wall of the arachnoid sac. The arachnoid membrane was adherent to the posterior surface of the spinal cord practically all the way up into the cervical region. II L. PED., second lumbar pedicle.

FIG. 13.—Dissection E, Type III. *This dissection was the one in the series which gave emphasis to the imperativeness of a mesial entrance of the needle into the subarachnoid space in lumbar puncture, as well as demonstrated the possible danger in puncturing at a level higher than the fourth lumbar interspace.* The posterior wall of the lumbar arachnoid sac, excepting that part of it outlined in white, which is here shown laid open, was adherent everywhere to the cauda equina. Thus most of the subarachnoid space lay entirely in front of the cauda equina. Since the fluid in the subarachnoid space in consequence of this anatomical arrangement must have lifted the cauda equina into a posterior position, it would be questionable whether in the upper part of the outlined area much sacculation of the arachnoid membrane behind the nerve-roots could have occurred. However in the lower part of this area, the mesial cleft, which was present below the upper border of the fourth lumbar vertebra, and to nearly the entire margin of which the arachnoid was adherent, furnished a situation for unobstructed entrance of a needle into the subarachnoid space. *Hence, a puncture free from nerve entanglement could here have been made only through the fourth lumbar or the lumbosacral interspace, with the needle directed mesially.* The width of the cleft was not essentially altered by the division of the arachnoid membrane. The photograph was taken with the body in extreme lumbar flexion, which here did not raise the sacral nerves away from their contact with the lumbosacral hollow, this notwithstanding the fact that the subarachnoid space extended down to the third sacral vertebra. The arachnoid membrane was adherent to the posterior surface of the spinal cord all the way up into the cervical region.

teristic feature of this type was a peripheral distribution of the nerve-roots of the cauda equina around the walls of the arachnoid sac, with adhesion of the roots to the latter. Besides the Dissection F illustrated in Figs. 14 and 15, another of the dissections was classified as one of this type, which had pre-eminently the anatomical characteristics of Type I, but presented this variation therefrom which was characteristic of Type IV, that three aberrant nerves came into relation with the posterior part of the arachnoid membrane, to which they were adherent. Two of

FIG. 15.

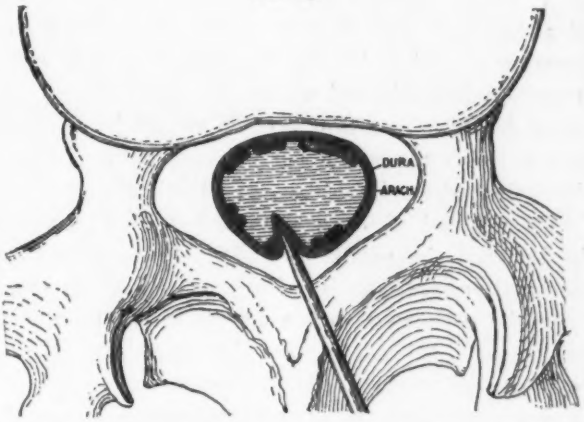


Diagram of cross section of Dissection F (Fig. 14, Type IV) at level of fourth lumbar interspace. It indicates the result of an effort made to injure these nerve-roots with a short hat pin which had not a sharply pricking point, directed against them from without the dura, subsequent to opening the spinal theca. When the dural flap, held by forceps, was allowed to yield a little before the pressure of the puncturing agent, repeatedly the latter would drive before it a wedge of dura, cleaving therewith a path between the nerve-roots, which would recede on either side of the wedge to places of safety before the membrane gave way. Only when the dural flap was drawn very taut by the holding forceps did it seem possible for the hat pin to prick the underlying nerve, which it would then carry inward on its point.

these nerves, running parallel and near together, formed loops bowing backward to near the median line opposite the third lumbar vertebra, and the other, a fine nerve filament, passed around posteriorly from the front opposite the fourth lumbar vertebra to a position near the median line. An effort to prick these nerves with a hatpin having not too sharp a point, directed against them from without the dura after the membranes had been opened, resulted in the slipping of the nerves out of the way, the same as occurred when this test was practised on the nerve-roots of Dissection F (see legend, Fig. 15).

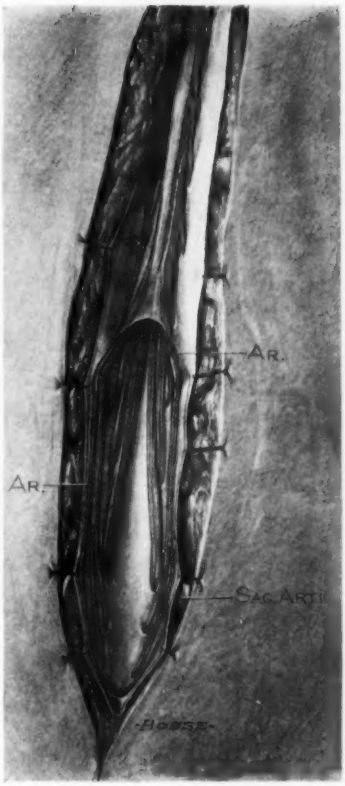
The picking up in the line of puncture of a nerve-root

attached to the arachnoid membrane, such as those found in the dissections of this type, on the extremity of a needle with a sharply pricking point might help explain those cases in which, on subarachnoid puncture, the flow of cerebrospinal fluid through the needle comes slowly in drops from evident partial obstruction of its calibre. The practical experience in the case of these dissections with the hatpin (see legend, Fig. 15) would argue in favor of the use of a puncturing needle without a sharply pricking point. The sacral nerve-roots in Dissection F were not made taut by the descent of the sacral lever.

TYPE V (Figs. 16 and 17).—The cauda equina here consisted of a flattened central stalk from which the nerve-roots, bound together in ribbon-like bands, diverged. The nerve mass arched transversely backward within the subarachnoid space. It can be seen in this dissection how it would be of the utmost importance to relax the sacral nerve bands before introducing a needle into the subarachnoid space. With the mesially lying nerve bands relaxed, from a knowledge of the presence of trabeculæ between the posterior wall of the arachnoid sac and the nerve bands underlying it, of a length of about one-quarter inch, it can be estimated that a needle could pass within the subarachnoid space for a depth equal to this figure before nerve structure would be touched. With deeper penetration, a needle having a sharply pricking point would then probably pick up the relaxed nerve bundle, thereby partially obstructing its calibre, while a needle having a dulled point would be more likely to push the nerve structure before it or pass around the side of the same. With, on the other hand, the mesially lying nerve bands made taut by forcing the sacral lever downward, it can readily be seen that it is quite possible for these bands to be drawn backward closely against the arachnoid membrane, in which event they would almost surely be pierced by the puncturing needle. Or supposing that, even in their tensed position, the full fluid space behind these bands should be still preserved, they would nevertheless be very liable to receive injury, from the fact of their being held rigidly, without any opportunity to yield or swerve.

The impalement of nerve structure on the point of the puncturing needle, in a type of cauda equina of this sort, might also be held accountable for slow dropping of the cerebrospinal fluid, as well as in the case of Type IV.

FIG. 14. FIG. 16.



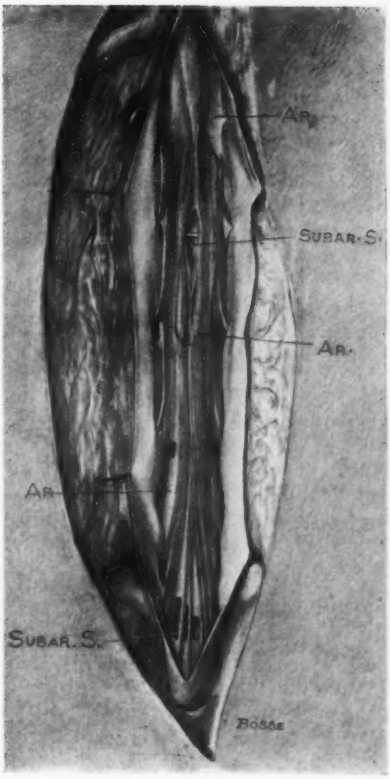
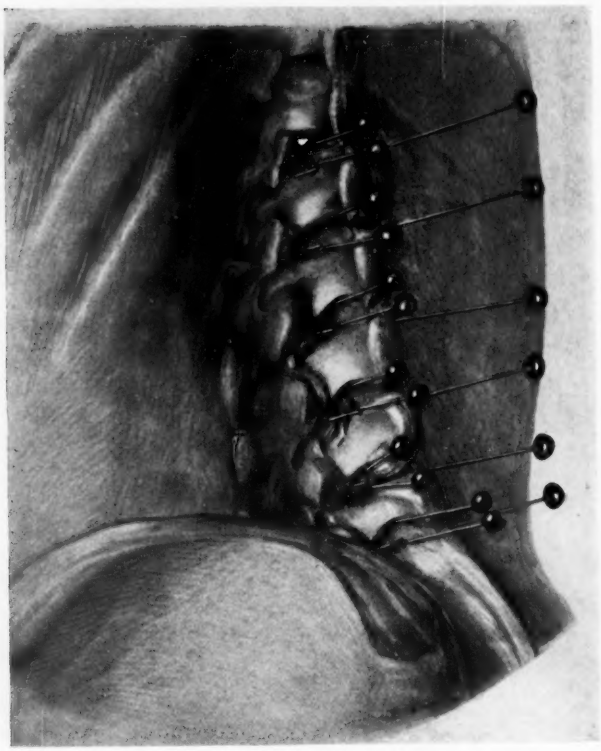


FIG. 14.—Dissection F, Type IV (6.6 per cent.) (cf. Fig. 15). The nerve-roots of the cauda equina were here separate and disposed peripherally within the subarachnoid space, each nerve being attached by delicate adhesions to the arachnoid membrane throughout its course. As soon as the subarachnoid space was laid open, the laterally and posteriorly situated roots were tacked with threads to the dura, in order to maintain their normal relationships to the spinal theca when the latter's flaps were spread widely apart. The sacral nerve-roots were not here made taut by the descent of the sacral lever, though the subarachnoid space reached to the lower border of the third sacral vertebra. This was one of the three out of eleven dissections, in which a subarachnoid space was found behind the cord all the way up into the cervical region.

FIG. 16.—Dissection G, Type V (6.6 per cent.) (cf. Fig. 17). The nerve-roots diverged in flattened ribbon-like bands from a central stalk. The nerve structure of the cauda equina arched transversely backward into the posterior region of the subarachnoid space, so that a greater area of the latter space was situated in front of the nerve-roots than behind them. The artificially made cleft in the central stalk, held open by a stick, demonstrates a considerable open space in front of the nerve structure. The relations of the arachnoid sac will be best understood by reference to the diagram of a cross section of this specimen (Fig. 17). The mesially lying sacral nerve-roots were taut in extreme descent of the sacral lever, but relaxed in the erect position of the body. The subarachnoid space reached down to the lower border of the third sacral vertebra. This was one of the three out of eleven dissections in which a subarachnoid space was found behind the cord all the way up into the cervical region.

FIG. 18.



View of posterior aspect of the lumbar portion of a spinal column, seen at an angle of about 40° with the median sagittal plane. The body was suspended in the almost vertical position. The bony limits of the interarcual spaces are indicated by the pins. *The small black pin heads* outline the extents laterally of these spaces. The third lumbar interspace shows considerable bony encroachment. The lumbosacral interspace is the largest of any, is nearest the skin surface, and its ligamentum subflavum offers less resistance to a needle than do the others. *The shorter large-headed pins planted in a forward direction* were introduced as nearly straight forward as possible at the upper and lower limits of these spaces close to the spinous processes. They therefore indicate the levels of these deep points with relation to the posterior extremities of the spinous processes. *The longer large-headed pins* were passed transversely through the interspinous ligaments close to the upper margins of the spinous processes. Excepting in the fourth lumbar interval, these pins protrude at the levels of the lower of the two large-headed pins directed straight forward in each interspace. In the fourth lumbar interspace the transverse pin lies a little higher. A large exostosis projected downward and to the left from the lower border of the spinous process of the fourth lumbar vertebra. The lower borders of the laminæ, projecting prominently backward, are considerably more superficial than are the upper borders, and therefore become, when touched by the needle point, bony guides (see p. 477).

Site of Greatest Safety for Performing Lumbar Puncture.—The one site at which lumbar puncture of the subarachnoid space could have been made without liability of injuring the nerve-roots in all of the fifteen dissections, using a needle not too sharply pointed (Figs. 15 and 17) and relaxing the mesially lying nerve-roots by sacral extension, was mesially in the interval between the fourth and fifth lumbar vertebræ (see Fig. 13). A puncture mesially in the lumbosacral space could probably have been done with equal safety in all the dissec-

FIG. 17.

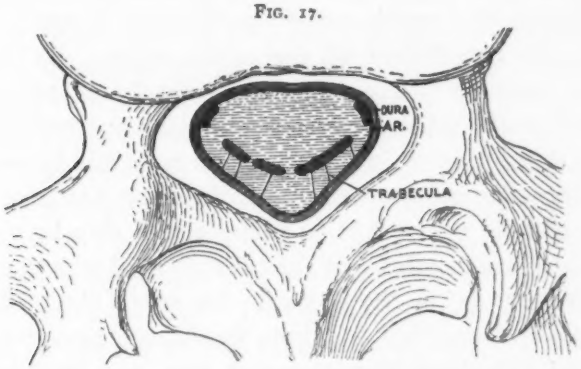


Diagram of cross section of Dissection G (Fig. 16, Type V) opposite the fourth lumbar interspace. Below the lower border of the fifth lumbar vertebra all the nerve-roots were adherent to the arachnoid. Above this level the arachnoid was firmly adherent over the posterior surfaces of the laterally situated nerve-roots of the cauda equina, while mesially it lay loosely over the posterior surface of the nerve structures, to which it was connected by delicate trabeculæ from about one-eighth to one-quarter inch in length, the shorter trabeculæ occupying the more lateral positions. Fluid tests were not made, but it would seem likely that in the presence of a fluid content within the arachnoid sac, *with the nerves relaxed by posture*, there would have been mesially in the posterior part of the sac a depth of about one-quarter of an inch of fluid which could be traversed by the puncturing needle before nerve structure would be touched.

tions, but it must be regarded as second in order of desirability, since at this level there was a greater tendency for the nerve-roots to become adherent to the posterior wall of the arachnoid sac, as well as for the subarachnoid space to become shallower. In one dissection the subarachnoid space terminated at the upper border of the first sacral vertebra.

THE TECHNIC OF LUMBAR PUNCTURE.

Quincke[7] early urged the importance of puncture of the spinal subarachnoid space only below the level of the conus

medullaris, and, as well, of making the puncture in the median line, to which latter procedure he made an exception in the case of muscular males, who have particularly tough median line structures, on whom he advised instead a puncture entering at a slightly lateral point and aimed at the posterior median line of the spinal theca. Dönitz,[8] after having produced half-sided anæsthesia in three instances consequent upon the injection of an anæsthetic solution into the lateral portion of the subarachnoid cavity with the patient in the sitting position, insisted upon the necessity of median puncture, so that the needle point should enter a median cleft between the two halves of the cauda equina described by Quincke, and thus avoid the laterally lying nerve-roots. Quincke[9] employed the lateral position for puncture in order that the elastic tension in the arachnoid sac could be measured apart from the influence of the hydrostatic pressure of the column of fluid that would be brought into play by the erect position. He contended that the subarachnoid pressure should not be lowered below the normal. He says (*Deuts. Kl.*, vi) that Krönig found that in adults the lumbar pressure in the horizontal dorsal position was 125 mm. and in the sitting position 410 mm. Hosemann,[10] of Rostock, measures the subarachnoid pressure by Quincke's method, in spinal anæsthesia, reducing it if raised, to 120 mm., or raising it if reduced, which is the condition more often found, by giving saline solution subcutaneously or by rectum. He thus controls the sequel headache. Müller[11] a year later reports a continuation of this practice with satisfaction at the Rostock Klinik.

Michelsson estimates roughly the subarachnoid pressure from the force of the stream through the needle, and withdraws more or less of the cerebrospinal fluid accordingly. Quincke[12] refers to Ossipow's experiments on dogs to demonstrate the effect on the circulation of the central nervous system of the withdrawal of the cerebrospinal fluid. He says: "The rather rapid removal of the fluid resulted not only in a hyperæmia of the cortex and substance of the brain and cord, but also in small hemorrhages, and, where the animals were allowed to live, in degeneration of the ganglion cells of the

cord." H. Tyrrell Gray [13] who, in spinal anæsthesia practises withdrawal of the cerebrospinal fluid until its flow is obviously influenced by the respiratory movements, writes: "The withdrawal of a considerable quantity of cerebrospinal fluid has no discernible constitutional effect on the patient."

The writer is inclined to believe, in theory, that the greater the reduction in the amount of the cerebrospinal fluid in the subarachnoid space, excepting to a point of complete depletion, the greater will be the distance through which the fluid that remains will shift cranialward should the head be lowered. Gray is very careful to keep the head elevated on account of using an anæsthetizing solution of a heavy specific gravity.

Dönitz employed the sitting posture in order that the needle could be driven forward more accurately in the median line. Both Quincke and Dönitz employed the position of extreme lumbar flexion. Sellheim [14] explained that the tension produced by forward bending of the body brought into prominence the median sagittal cleft, between the two halves of the cauda equina. Quincke advised puncture below the second lumbar vertebra to avoid the conus medullaris. Bier [15] punctured between the second and third, or first and second lumbar vertebræ. Colombani [16] preferred the fourth lumbar interspace.

The Needle.—Strauss [17] has said that to penetrate the median interspinous ligamentous structures the point of the puncturing needle must be as sharp as possible. He first used Quincke's needle and then Bier's. Sellheim [18] advocated the use of a needle as blunt as possible so as to preserve the sense of touch. He says that the angle of obliquity of the long axis of the opening in the needle point with the shaft should be about 50°, and that the margin of the opening should be rounded off. The needle should be provided with an obturator which exactly fits the point.

The writer is of the opinion that a moderately blunt needle, as well as giving greater perception to the sense of touch, is less likely to cause injury to any nerve-roots it may meet or to become obstructed by such roots than is a sharply

pointed one (see Fig. 15, and descriptions in the text of Types IV and V). Bier recommended that the point of the needle should be short to ensure its complete entrance within the subarachnoid space, since a long point, if arrested when but partially passed within the spinal theca, might both tap the subarachnoid space and at the same time be the cause of a peridural spilling of the injected fluid.

Slamjer [19] advises that the needle should have a short oblique point for the same reason. Barker [20] avoided this difficulty by threading through his needle a canula which projected beyond the point. The needles should be made of platinum or pure nickel, neither of which metals rust, the importance of which lies in the fact that the drugs used for spinal anæsthesia are decomposed by an alkali, and therefore the implements with which they come in contact must be boiled in plain water. The diameter generally recommended for the needles is about 1 mm. Slamjer suggests that a needle of too great a diameter may make so large a puncture in the spinal membranes as to allow a reflux of cerebrospinal fluid through it after the needle has been withdrawn. Sellheim describes a manner of holding a relatively blunt needle when puncturing in the median line, in a way to employ the sense of touch, as follows: "The puncturing needle, after penetration of the skin and the superficial ligamentous structures, is strongly grasped by the index finger and thumb of each hand, while the other fingers find as many points of support as possible on the back, on either side of the site of puncture. In this position a deep touch perception can be most delicately observed by the play of the fingers." He could thus determine by the sense of touch when the point of the needle had passed the resistance of the ligamentous structures. He estimated the distance between the ligamentum subflavum and the cerebrospinal fluid in corpulent people to be about 1 cm.

Hemorrhage.—Hemorrhage arising from spinal puncture may be either epidural or subdural. If pure blood flows out through the needle, the source of the hemorrhage is epidural. If blood-tinged cerebrospinal fluid is drawn, the source is

subdural (Quincke). Since the posterior epidural venous arcades underlie the bony arches of the lumbar spine (p. 451), and since the mesially lying anterior epidural venous plexuses occupy only the transverse hollows of the posterior surfaces of the lumbar vertebræ (p. 451), there are therefore normally no sizable epidural veins in the line of a straight, forward puncture, which is directed toward an intervertebral disk, and the liability of hemorrhage occurring from this source is very slight. Borschardt[21] reports a case, however, of a 60-year-old man with an enlarged prostate, in which after an injection of 0.06 g. tropacocaine, followed by high pelvic elevation, collapse and death supervened. The autopsy showed an epidural hemorrhage which with the high pelvic elevation had flowed upward to the second or third cervical vertebra, while the sacral canal contained no blood. Borschardt does not attribute the cause of death any more to the hemorrhage than to the tropacocaine and high pelvic elevation. Bolton[22] has questioned whether it would be possible for the cord to be compressed at all by bleeding into the epidural tissue.

Concerning subdural hemorrhage, in König's case of paraplegia (p. 481), the subarachnoid injection of stovaine was made directly upon having drawn through the needle cerebrospinal fluid colored light red, regarding the impropriety of having done which, König, in reporting the case, made the following reflection: "We must regard as an absolute rule the principle already laid down by Dönitz, though for somewhat different motives, to inject the anæsthetic only when clear liquor is drawn." Bier says in this regard: "If blood drops forth and is not soon succeeded by clear liquor, then the needle should be withdrawn and reintroduced in another intervertebral space." Michelsson says: "A fresh puncture seems to us necessary only in those cases where the cerebrospinal fluid is bloody and does not quickly clear up. In the cases where we injected nevertheless, we most always have seen total failures." He regarded that the blood admixture with cerebrospinal fluid neutralized the effect of stovaine.

Slow Dropping of the Cerebrospinal Fluid from the Punc-

turing Needle.—In seeking for the cause of this manifestation among the anatomical findings of this work, the evidence has been in favor of attributing a slow dropping of the cerebro-spinal fluid through the needle to the impalement of a nerve on the point of the latter (see text Types IV and V, pp. 465 and 466) which would manifestly be more likely to happen with the use of a needle having a sharply pricking point and in the presence of tensed nerve-roots lying in the line of puncture, than with a needle having a relatively blunt point and with the mesially lying nerve-roots of the cauda equina relaxed. Bier says on this subject: "The anæsthetic should never be injected before the liquor flows out in quickly following drops. The neglect of this rule causes most of the so-called 'failures.' The needle should be turned with very slow forward pushing or backward drawing until the liquor flows right."

The Cardinal Principles.—The writer would enumerate these as follows:

1. The posture of the patient should be one embodying pelvic extension (elevation of the sacral lever), for the purpose of assuring relaxation of the mesially lying sacral nerve-roots of the cauda equina, that they may the better elude the needle-point.

2. Puncture should be made only in the fourth lumbar (preferably) or the lumbosacral interspace.

3. The point of the needle should be aimed at the posterior median line of the spinal theca (Quincke, Dönitz, Gerstenberg and Hein, Sellheim, and Fig. 13).

4. The point of the needle should be short to ensure its complete entrance within the subarachnoid space (Bier), and relatively blunt both for adding delicacy to the sense of touch (Sellheim), as well as to reduce to a minimum the liability of impalement upon it of the nerve-roots (see text Types IV and V, pp. 465 and 466).

The question would now arise, as to what plan of technic would best inculcate these principles.

The Posture (sacral elevation).—In the erect position of the body the pelvis is tilted sufficiently backward to relax

the sacral nerve-roots, and also the amount of space between the spinous processes (Fig. 18), though less than with acute lumbar flexion, is sufficient for the performance of median lumbar puncture. In forced lumbar extension the spinous processes crowd closely together, which movement, when suddenly made by the patient during median lumbar puncture, may cause breaking of the needle.

In the lateral position, pelvic extension can be maintained by straightening the dependent thigh, and then, in order to keep the balance, the leg and thigh of the opposite side can be flexed until the foot of this side rests upon the knee of the dependent extremity.

The Choice of the Route of Puncture.—In this connection there arises the question of the necessity for the use of a needle with a relatively blunt point for the purpose of lessening the danger of injury to the nerve-roots, the fact for consideration being that a needle of this description can be passed through the intercepting structures of the lateral route with a delicacy of touch which is impossible by the median route. So that, if the lateral route with the use of a relatively blunt needle can be shown to at least be as safe as the median with the use perhaps of a sharper needle, it would naturally become the route of choice.

Certain of the anatomical facts here demonstrated would seem to throw some light upon this problem. The three dissections E, F, and G (Figs. 13 to 17) were the only ones of this series in which the route of puncture or shape of the needle point could have had any bearing on injury to the nerve-roots. In every one of the other 12 dissections, the anatomy was such that, with sacral lever raised, the subarachnoid space could have been tapped through any one of the three lower interarcual spaces, without danger of injuring any of the nerve-roots by either lateral or median route, and with a sharply pointed needle as well as with a blunted one.

The original operation of median lumbar puncture proposed by Quincke was based upon the proposition that the cauda equina invariably divided at the conus into two lateral

halves, having a cleft between them from 2–5 mm. in breadth, through which interval alone the cerebrospinal fluid must be drawn. Dönitz and Sellheim in their essays on technic reiterated Quincke's argument for median puncture.

Out of the whole series of 15 dissections here presented, Dissection E (Fig. 13) was the only one in which the cerebrospinal fluid would have had to have been drawn from between the two halves of the cauda equina. The cleft in this dissection did not visibly spread on cutting through the arachnoid window attached to its two sides, so that the illustration gives a good idea of the available space there would have been here for puncture. In this dissection an exact median puncture through the fourth lumbar interspace would have been the ideal operation. Yet in seeking to establish one technic to best meet all anatomical variations, provided in all other complicating arrangements of the nerve-roots (Dissections F and G) it can be shown to be desirable to employ a relatively blunt needle and a lateral route of puncture, it would seem to be the question for consideration in the case of Dissection E, whether for it too the blunted needle and lateral route might not be utilized at least as a very good compromise in place of median puncture if not as an equally good procedure. (See *mesial puncture of the spinal theca by a lateral route*, p. 475.)

The other two dissections, F (Figs. 14 and 15) and G (Figs. 16 and 17), for special consideration, are the ones which argue strongly for the use of the relatively blunt needle, though for different reasons, Dissection F in order that the needle may be one that can drive a wedge of dura between the nerve-roots before it penetrates, and Dissection G in order that the needle may be one that the posteriorly lying nerve bands, relaxed by elevation of the sacral lever, can best elude. In neither of these dissections does the importance of a direct forward median puncture for entrance into the subarachnoid space seem to be demonstrated, and on the other hand there would seem to be every reason for using as blunt a needle as possible, introduced with the utmost delicacy of

touch, which conditions are best fulfilled by the lateral route.

Anatomy of Median Lumbar Puncture.—A tubercle projects downward from the lower margin of a lumbar spinous process close to its posterior extremity, so that in performing median puncture the needle should be made to follow as closely as possible the upper border of the lower spinous process of the interspace through which it is passed, to avoid encountering the tubercle.

In median lumbar puncture the needle is liable to some little deflection from the exact median plane. The writer planted two hat pins straight forward in the spinal canal, one introduced in the interspinous interval in a line which was thought to occupy the exact median plane, and the other, one-third inch lateral to the first. On dissecting out the points, they were found to have entered the spinal theca close together a little lateral to the middle line. Gerstenberg and Hein say that a little deviation of the needle from the median line makes no difference.

The supraspinous ligament measures about one-quarter inch across, while the interspinous ligament at its middle portion is only about one-twelfth inch thick. Quincke estimated the depth of lumbar puncture to be usually from 4 to 6 cm.; in large muscular men from 7 to 8 cm.; and in fat people even to 10 cm.

The depth of puncture in the lumbosacral interspace is perceptibly shallower than is that in the lumbar interspaces above.

Mesial Puncture of the Lumbar Spinal Theca by a Lateral Route.—H. Tyrrell Gray[23] practises lateral puncture exclusively. He says: "These dangers" (those of lateral puncture) "I am convinced have been greatly exaggerated." He states that in some hundreds of lumbar punctures the nerves had been touched by the needle or canula on only three occasions. Gray, from a point just lateral to his finger-tip placed on the interspinous interval in the median line of the back, directs the needle very slightly upward and inward. "The needle can be felt in its course to penetrate two re-

sistances: (1) the ligamentum subflavum, and (2) the dura mater." The writer has employed the same deep guides for a number of years in a limited experience with lateral lumbar puncture, using a needle without a sharply pricking point, since in this way he had found that he could be guided by the sense of touch. Slamjer, in reporting 2700 cases of lumbar anæsthesia with tropacocaine, says: "The puncture was either lateral or median without our having seen any remarkable difference resulting."

The ligamentum subflavum in the lumbosacral interspace is thinner than are those in the lumbar spaces above, and consequently offers a considerably less resistance to the penetrating needle.

In fat people, in whom the spinous processes cannot be differentiated by palpation through the skin, *the lumbar interspinous interval can be located* in two ways, one by prodding with a needle from a slightly lateral position across the median line structures, and the other by touching with the needle the lower border of a lamina near where it joins the spinous process. The latter site is recognized by its superficial location, three-fourths to one inch beneath the skin surface, the conformation of a lumbar lamina exhibiting a rather prominent backward slope from above downward, so that its lower border overhangs considerably the upper margin of the lamina immediately below it (Fig. 18). Consequently if the puncturing needle, introduced close to the median line structures, strikes bone thus superficially, the point of contact must be offered by this prominent lower border of the lamina, which indicates that the course of the needle is just a little above the level of an interarcual space.

In order to as accurately as possible penetrate the posterior median line of the spinal theca with a needle introduced through a lateral route, the point of the needle must first be made to touch some deep guide from which, as a point of ultimate departure, it can take a short and direct course to its final destination. With the attempt to direct the needle from a point of slightly lateral entrance on the skin surface

in one straight line to the posterior mesial area of the spinal theca, the needle point may very easily get outside of the limits of the interarcual space. Thus it was found by this method that the point could pierce the interspinous ligament and impinge on the lamina of the opposite side, or that it could strike the under margin of the spinous process. The deep guide in the procedure here proposed is the ligamentum subflavum or the bone adjacent to it, which is met by the needle when passed straight forward through the erector spinæ muscle, parallel with and closely adjacent to the interspinous ligament. The close relationship of the course of the needle to the latter structure is advisable, in order that the needle can be made to enter the posterior mesial area of the theca with as little inclination from the median sagittal plane as possible. The point of entrance selected was therefore one quarter inch from the median line of the back, and the needle, taking thence a straight forward course, should consequently reach the level of the interarcual space also one quarter inch from the median sagittal plane. A short longitudinal stab wound of the skin should be made at the site of entrance of the needle. This incision is necessary for the entrance of a relatively blunt needle, while at the same time it does away with the binding influence of the skin on the shaft of the needle, as well as avoids the danger of contamination of the needle by the bacteria of the skin.

The resistance of the interarcual area is encountered at a depth of from one and one-half to two inches beneath the skin, excepting opposite the lumbosacral interspace where the depth is less. After the needle has encountered the resistance of the spinal column (usually that of the ligamentum subflavum), it should not be attempted to push the instrument straight through into the subarachnoid space, but instead, before trying to complete its introduction, it should first be slightly withdrawn until its point lies free in the muscle, and then from this latter position it should be given its direction toward the posterior median line of the spinal theca, which is done by inclining it at an angle of about 5 degrees

with the median sagittal plane. The needle will then usually pass unobstructedly through the firm structure of the ligamentum subflavum to penetrate the spinal theca. Sometimes, however, the angle must be increased to about 7 degrees to get over a lateral bony obstruction. Or, if this slightly increased slant of the needle be of no avail to elude the bony opposition, then the latter is probably due to a high projection of the upper margin of the spinous process, to get above which, the point of the needle should be gradually worked upward, maintaining all the time the inward inclination of 5 degrees, until finally the point finds entrance beneath the middle of the upper bony arch of the space. An upward slant of the needle of from 5 to 10 degrees may be necessary.

Certain advantages of the lateral route over the median can be summarized as follows:

1. The needle can be guided more by the sense of touch.

2. There can be used a needle with a less sharp point, which both aids the sense of touch and is less liable to cause nerve injury.

3. With a correct technic, the posterior mesial area of the spinal theca can be entered in almost as straight forward a direction as is possible by the median route, and apparently about as near the median line.

4. There is no danger of breaking the needle.

5. The operation is capable of performance, if desired, in the position of extreme lumbar extension.

PARALYTIC SEQUELS OF LUMBAR PUNCTURE AND THE LUMBAR INJECTION OF A SPINAL ANÆSTHETIC.

But one reference to a paralytic sequel following lumbar puncture *per se,* was found in literature. Slamjer,[24] speaking of permanent nerve paralyses following spinal anæsthesia, says: "Quincke saw such a paralysis occur as a result of simple lumbar puncture, the reason for which he attributed to a hemorrhage in the nerve substance." There were found, however, a number of reported cases having paralytic sequels following the lumbar injection of a spinal anæsthetic, a brief

consideration of which it was thought might be illuminating to the subject matter of this paper.

These paralyses following the lumbar injection of a spinal anæsthetic became apparent either closely consecutive to the recovery of the patient from the effects of the anæsthesia, or else later after an interval of complete restoration of function to the patient. They are regarded to be due either to trauma inflicted on the nerve structures by the puncturing needle, or to some irritative action of the solution injected. It can be seen that paralyses attributable to the former cause must be limited to the lower half of the body, and that their onset, as in the case of any severe nerve injury, ought to be immediate. The late occurrence of a paralysis would seem to be at total variance with a traumatic origin, and might consequently be regarded as characteristic of an irritation by the anæsthetizing drug. In support of the latter proposition is the fact that paralyses of the upper extremity and more frequently of the eye muscles, following the lumbar injection of a spinal anæsthetic, which could by no possible logic be attributable to the traumatism of a lumbar needle puncture, are characterized by a late onset. These late occurring paralyses are sometimes permanent.

Owing to an almost general obedience to Quincke's early injunction to enter the puncturing needle below the conus medullaris, which could then only encounter individual nerve-roots, the cases of paraplegia following lumbar anæsthesia attributable to the needle puncture have been few. On the other hand isolated paralyses of the lower half of the body following lumbar anæsthesia, which might be due to injury of individual nerve-roots of the cauda equina, are more frequent. The latter sequels seem to affect exclusively the bladder and anus and the area of distribution of the peroneal nerve. That the nerve-roots of supply to the bladder and anus, which are the third and fourth sacral, should be ones of selection for injury by the needle it is easy to understand, since they occupy the most mesial position of all the nerve-roots of the cauda equina, and consequently, excepting where a mesial cleft exists, lie in line with a median puncture.

As regards the liability of causing injury to an agglutinated mass of nerve-roots by puncturing them with a needle, Dönitz's [25] three cases of half-sided anæsthesia, and that of Trautenroth,[26] resulting from the injection of the anæsthetic solution laterally within the spinal theca, are instructive. Dönitz employed the sitting position, so that any possible influence of gravity to retain the injected fluid all on one side could be eliminated. No ill results were recorded. Trautenroth, with the patient in the left lateral position, produced a right-sided anæsthesia, so gravity in his case too could have played no part. He introduced the needle to the left of the median line and aimed it obliquely toward the median line. The patient experienced a severe pain in the right leg, whereupon the operator, without withdrawing liquor, injected 0.06 g. tropacocaine with resulting anæsthesia of the right lower extremity only. The other side of the subarachnoid space was then injected with 0.045 tropacocaine. Headache was the only sequel. Oelsner and Kroner [27] have published a case, in which, during the operation for spinal anæsthesia, there was pain in the right leg as if a nerve of the cauda equina had been struck. The pain disappeared after one to two minutes. There was no change in the pulse or respiration, and there were no serious complications or sequels.

The comparative infrequency with which paralysis has followed lumbar puncture, in the face of the indisputable anatomical evidence here presented that nerve-roots may so frequently be in relation with the posterior arachnoid wall opposite the second and third lumbar interspaces, would seem to be in evidence that the trauma of a needle penetrating nerve-roots of the cauda equina is generally well borne. This observation, however, should not be construed as furnishing a reason why the utmost punctiliousness should not be observed to avoid the nerve-roots in practising lumbar puncture.

1. Whole Lower Extremity Paralyses Immediately Following Spinal Anæsthesia.

1. TRAUTENROTH: *Ein Fall von schwerer Stovainvergiftung nach Lumbalanæsthesie nebst Bemerkungen über halbseitige Anæsthesien, Deuts. med. Wochenschrift, 1906, p. 7. Forceps extraction.*

Patient on left side. Point of entrance of needle between the first and second lumbar vertebræ about 1 cm. to left of median line. No cerebrospinal fluid came through the needle, but nevertheless half a Pravaz syringeful of 1:1000 adrenalin solution was injected. With a new puncture between the second and third lumbar vertebræ, cerebrospinal fluid was drawn; 1 in 1000 adrenalin solution was now injected, followed in three minutes by 0.06 g. stovaine. Ten minutes after the injection the woman was in bad condition. Pulse small and slow. Breathing slow and superficial. Cyanosed. The anæsthesia reached to the neck. Fifty minutes after the birth, sensation had returned to the navel, and the lips were red. The left leg could not be moved by the patient for seven hours and the right leg until several hours later. On the following day the patient could not properly lift the right leg. Sudden severe headache on the night of the fourth day with general pains over the body. The right leg was as though asleep. Ninth day right leg seemed to the patient icy cold, as though dead. No temperature difference between the right and left legs. Not until five weeks after the puncture did the patient first leave her bed, in which she had remained on account of pains in the back and lameness in the right leg. She could walk only with trouble. The temperature had been normal.

2. König: *Bleibende Rückenmarkslähmung nach Lumbalanæs., Münch. med. Wochenschrift, No. 23, 1906, liii, 1112.*

Needle introduced between the third and fourth lumbar vertebræ, whereupon the patient experienced pain. As soon as the liquor, which was colored light red, came from the needle in drops, stovaine-Riedel (0.06 stovaine) was injected. Anæsthesia of lower abdomen. "The lost function about from the navel downward, including bladder, rectum, and extremities did not return." On the fifteenth day a lumbar puncture was made, drawing a light red sterile fluid containing isolated red cells and mononuclear leucocytes. Patient died after three months with cystitis, etc. Autopsy: The spinal cord from about the level of the ninth vertebra downward was adherent to the dura. In the lumbar portion a space remained in which there was found no abnormal fluid. In the lower dorsal and in the lumbar regions the cord on section presented the picture of softening.

3. Bosse (Hildebrandt): *Berl. klin. Wochenschrift, 1906, xliii, 369. Disk. zu Lazarus.*

Age 59. Examination of prostate. Stovaine. At the conclusion of lumbar anæsthesia, without other toxic sequels, the paraplegia continued. The paralysis on one side lasted until the fourth day, while the paralysis on the other side remained until death, four weeks later, of an ascending nephropyelitis.

4. Goldschwend: *Ueber 1000 Lumbalanæs. mit Tropakokain, Weiner kl. Wochenschrift, 1907, xx, 1098.*

"In high grade disquieting were the rare cases of long lasting paraplegia (3 in 1000). In the most severe case it lasted eight days, after which the motility gradually returned. . . . The paraplegia affected only the lower extremities and not the bladder."

II. Whole Lower Extremity Paralyses Following a Complete Recovery of Function After Spinal Anæsthesia.

WALTHER: *Bull. et Mem. de la Soc. de Chir. de Paris, 1905, xxxi, p. 214. Meningo-myelite consec. a la rachicocainisat.*

Male, age 20. Case admitted to hospital with the following history: February 25, 1903, subarachnoid injection of cocaine. No sequels. May 27, 1903, subarachnoid injection of cocaine without loss of sensibility. Nothing abnormal until third day, when motion and sensation of the lower extremities began to fail and progressed until at the end of ten days they had entirely disappeared. Third week incontinence of urine and fæces. After four or five months control of anus and bladder had returned to normal. After eight months the movements of the lower extremities began to return a little. After 21 months he still could not walk. Lower extremities showed some contracture, increased tendon reflexes, and spasticity. Sensation to heat, touch, and pain was present. The case was diagnosed as one of meningomyelitis.

DANDOIS: *Journ. de chir. et Annal de la Soc. Belge de Chir., 1901-4, p. 282.*

External urethrotomy. Age 57. 0.02 cocaine. On eighth day pains in pelvis and lower extremity. Ninth day complete paraplegia. Sensation preserved. Delirium. No fever. Twenty-fifth day slight movements in lower extremities, followed by complete recovery.

III. Localized Paralyses of the Lower Half of the Body.

HENKING: *Münch. med. Wochenschrift, 1906, p. 2428. Erfahrungen über Lumbalanæsthesia mit novocaine.*

Age 28. Hernia. Novocaine. Perfect anæsthesia. After 12 hours patient became restless. Incontinence of fæces and urine lasting 60 hours.

BORSZEKY: *Beitrage z. kl. Chir., lviii, 1908, 651.*

Borszeky refers to a case of bladder paralysis following spinal anæsthesia reported by Wiener, of a "35-year-old perfectly sound man who suffered a total incontinence. The condition of the patient improved after sixteen months only in so far that he could hold his urine two to three hours by day, but not at night. Furthermore erection was incomplete and libido was entirely absent."

STRAUSS: *Deutsche Zeitschrift f. Chir., lxxxix, 1907, 275.*

Strauss reports that after performing lumbar anæsthesia with stovaine on about 300 cases without serious accident, there occurred on the same day two cases of paralysis of both bladder and rectum following lumbar anæsthesia with stovaine. The paralyses of the sphincter ani lasted 10 days. The bladder paralysis lasted in one case 1½ months, and in the other after 3 months a slight paresis still existed.

MICHELSSON: *Arch. f. kl. Chir., xcii, 1910, 657.*

In 400 cases of lumbar anæsthesia there followed disturbances of motion in four cases. Two had paresis of the extremities. Another had a paralyzed sphincter for four days following operation, and the other for six days following operation could not empty his bladder.

BONDY: *Gyn. Rundschau, iv, 1910, p. 99.*

Of peripheral paralyses occurring in 1000 cases of lumbar anæsthesia,

there were nine of the peroneal nerve, and trophoneurotic disturbance 10 times.

SELLHEIM: *Medizinische Klinik, 1910, vi, p. 5.*

In 1000 operations under spinal anæsthesia, there were nine cases of peroneal nerve paralysis, all of which disappeared completely.

KÖNIG: *Hohmeier u. König. Sammelforschung über die Lumbalanæsthesie im Jahre 1909. Verhandl. d. Deutsche Ges. f. Chir., xxxix, 1910, p. 481.*

König collected from the *Centralblatt für Chirurgie* in the years 1908–09, eight reported cases of paralysis of the leg following lumbar anæsthesia, usually limited to the peroneal nerve region, some of which were permanent.

IV. Unclassified Cases.

BAINBRIDGE: *Analgesia in children by spinal injection, with a report of a new method of sterilization, etc. Medical Record, 1900, lviii, p. 937.*

Age 7. Slight lumbar kyphosis. Puncture to right of median line between twelfth dorsal and first lumbar vertebræ. Cocaine 9 mms. of a 1 per cent. solution. In nine minutes analgesia up to lower jaw. On third day, patient seemed stupid and did not move right arm and hand, and the legs were drawn up. Eighth day the legs could be extended and patient moved the right arm. Thirtieth day, "he is in excellent condition, better than before operation."

FÜSTER: *Bruns Beiträge z. kl. Chir., 46, p. 1. Erfahrungen über spinal analgesie.*

Age 34. Appendicitis. Injection between second and third lumbar vertebræ. No anæsthesia and ethyl chloride given. Symptoms of spinal meningitis developed with opisthotonus. Eighth day lumbar puncture drew few drops of sanguinolent fluid which was sterile. Tenth day sudden improvement. Eighteenth day cured.

ALLEN: *Spinal anæsthesia. Boston Med. and Surg. Journ., clxiii, 1910, p. 715–718.*

Age 55. Double inguinal hernia. 1.5 c.c. stovaine Billon injected through second lumbar interspace. Rather marked Trendelenburg position for three minutes then laid flat. Soon after the beginning of the operation the patient lost consciousness and the respirations became Cheyne-Stokes in character. Had complete left hemiplegia which cleared up in less than twenty-four hours, excepting a slight paralysis of the left wrist which persisted two days longer. During the next twenty-four hours there developed a complete paralysis of right leg. This persisted for two weeks. It then gradually cleared up, and in two months was entirely well.

NOTE.—The writer wishes to acknowledge his appreciation of the courtesies shown to him by Dr. H. D. Senior, the Professor of Anatomy at the New York University and Bellevue Hospital Medical College, during his conduction of this work in Dr. Senior's department.

REFERENCES.

[1] Key and Retzius: Studien in der Anatomie des Nervensystems und des Bindegewebes, 1828.

[2] Propping: Die Mechanik des Liquor Cerebrospinalis und ihre Anwendung auf die Lumbalanæsthesie, Mitteil a. d. Grenzgeb. d. Med. u. Chir., xix, 1908–9, 441.

[3] Quincke: Die Technik der Lumbalpunction, Urban und Schwartzenberg, Berlin u. Wien, 1902.

Über Lumbalpunction, Deutsche Klinik, vi[1], 1906, p. 351.

[4] Gerstenberg and Hein: Anatomische Beitrage zur Rückenmarks-anæsthesia, Zeitsch. f. Geburtsh. u. Gyn., lxi, 1907–08, p. 524.

[5] Magendie: Recherches physiologiques et cliniques sur le liquide céphalo-rachidien ou cérébro-spinal, Paris, 1842.

[6] Rehn: Archiv. f. kl. Chir., xc, 1909, p. 329.

[7] Quincke: Ibid.

[8] Dönitz: Technik Wirkung, und Specielle Indicationen der Rückenmarks-anæsthesia, Verhandl. d. deutsch. Gesell. f. Chir., xxxiv, 1905, Th. 2, 527.

[9] Quincke: Die diagnostische und therapeutische Bedeutung der Lumbalpunction, Deut. med. Wchsft., 1905, xxxi, 1825, 1869.

[10] Hosemann: Verhandl. d. deut. Gesell. f. Chir., 1909, p. 17.

[11] Müller: Discuss. Hohmeier u. König., Verhandl. d. deut. Ges. f. Chir., 1910, p. 481.

[12] Quincke: Deut. med. Wochenschrift, 1905, p. 1829.

[13] Gray: Internat. Clinics, iv, 1910, p. 71.

[14] Sellheim: Uber Geschichte, Anatomie, und Technik der Rückenmarks-anæsthesie, Medizinische Klinik, 1910, vi, p. 5.

[15] Bier: Das zurzeit an der Berliner chir. Universitatsklinik übliche Verfahren der Rückenmarksanæsthesia, Deut. Zeit. f. Chir., xcv, 1908, p. 373.

[16] Colombani: Über 1100 Falle Lumbalanalgesie, Weiner kl. Wochenschrift, xxii, 1909, p. 1336.

[17] Strauss: Die gegenwartige Stand des Spinalanalgesie, Deutsche Zeit. f. Chir., lxxxix, 1907, 275.

[18] Sellheim: Ibid.

[19] Slamjer: Über die Rückenmarksanæsthesie mit tropacocain, Beitrage zur kl. Chir., lxvii, 1910, p. 1.

[20] Barker: British Medical Journal, 1907, i, p. 665; and *Ibid*, 1908, i, p. 244.

[21] Borschardt: Discuss. sp. anæsthesia, Verhandl. d. Deut. Ges. f. Chir., xxxviii, 1909, p. 25.

[22] Bolton: The Principles of the Treatment of Injuries of the Spinal Cord, ANNALS OF SURGERY, Philadelphia, xxx, 1899, p. 171.

[23] Gray: A Study of Spinal Anæsthesia in Children and Infants, Lancet, clxxvii, 1909, p. 913.

[24] Slamjer: Ibid.

[25] Dönitz: Ibid.

[26] Trautenroth: Ein fall von Schwerer Stovainvergiftung nach Lumbal-anæsthesia nebst Bemerkerungen über Halbseitige Anæsthesien., Deut. med. Wochenschrift, 1906, p. 7.

[27] Oelsner and Kroner: Deut. Zeitsch. f. Chir., xcv, 1908, p. 386.

THE TECHNIC OF END-TO-END ARTERIAL ANASTOMOSIS.*

WITH REPORT OF A CASE.

BY ALBERT EHRENFRIED, M.D.,

AND

WALTER M. BOOTHBY, M.D.,

OF BOSTON, MASS.

VASCULAR anastomosis has developed chiefly within our own day. Its history begins, however, with the first arterial suture on June 15, 1759, when Hallowell, at the suggestion of Lambert, closed a wound of the brachial artery by passing a small steel pin, rather more than a quarter of an inch in length, through the two lips of the wound and then twisting a thread around it, as in the hare-lip operation. The closure was successful, and the pulse remained thereafter nearly as strong as in the other wrist. Asman, after fourteen years (1773), on the basis of four unsuccessful experiments on dogs, concluded that a vessel could not be sutured by this method with preservation of its lumen. Wattmann seventy years later (1843), reported that he had performed lateral ligation of a vein with success by holding up the edges of the wound with forceps and surrounding it with a ligature. Nicaise in 1872 maintained that lateral suture was practicable, and stated that Ollier and Gensoul had both performed it. Hirsch (1881) and Braun (1882) did important work on lateral suture, while Gluck (1882) devised a small ivory clamp for closing arterial wounds. Jassinowsky, in 1889, reviewed the general literature of the subject of lateral suture, published an extensive series of personal experiments, and established the procedure on a sound basis.

* The experimental work upon which this paper is based was performed in the Laboratory of Comparative Physiology at the Harvard Medical School, through the kindness of Dr. W. T. Porter.

Eck, investigating the physiology of the liver, performed in 1877 successful lateral anastomoses between the vena cava and the portal vein of dogs. His technic resembled that of lateral intestinal anastomosis, except that the anastomotic openings were not made until all the stitches had been placed. He used for this purpose a pair of fine scissors, to each tip of which was soldered a length of silver wire terminating in a curved needle. After the posterior line of sutures had been made, these needles were passed through the vessels (one the vena cava and the other the portal vein) at points determining the length of the incision. The anterior line of sutures was then placed, the scissor-blades were pulled into the vessels by means of the wires, and the veins cut between the two lines of sutures. This technic was improved by Stolnikow (1882), Hahn, Massen, Nenchi, and Pawlow (1893), and others, and the subject of Eck fistula forms an important chapter in blood-vessel surgery.

Von Horoch in 1888 tried to sew together the ends of an artery which had been cut across; he was unable to accomplish this without interfering with its patency. Robert Abbe, 1894, of New York, was the first to successfully perform end-to-end anastomosis; he divided the abdominal aorta of a cat and "tied each end over a glass bobbin by a fine silk thread, and tied the ends together." Queirolo and Masini, working on the Eck fistula, introduced in 1895 an appliance consisting of a tube of glass through which one cut end of the artery was threaded and cuffed back and then invaginated into the other end and held in place by a ligature. Nitze in 1897, demonstrated a similar anastomotic aid made of ivory, and Von Karltrew working also on the Eck fistula, improved the technic of its use in 1899. Payr in 1900, apparently without knowledge of the above methods, described in detail two appliances made of an absorbable material (magnesium); for a short time Payr's protheses were quite popular, and from one form, similar to that of Queirolo, the Crile cannula has developed.

While these men were perfecting anastomotic aids Murphy,

of Chicago, was attempting to develop a technic of suture without aids, and in 1897 he described a successful method of anastomosis by invagination. When dealing with moderately sized vessels, this method proved to be superior to that of Payr. Several men made attempts to improve the technic, especially Bouglé in 1901. Coincidently with Murphy, Jaboulay and Briau developed a method of end-to-end anastomosis by means of interrupted mattress sutures with evagination of the intima, and in 1898 they presented a specimen to the Medical Society of Lyons, in which there was a perfect union of the endothelium without any thrombus formation. Salomoni in 1900 independently devised a technic similar to that of Jaboulay and Briau. The method of Jaboulay and Briau was improved by the former's pupil, Carrel, into the method which is now generally used.

It was in 1902 that Carrel first described his now famous method of circular suture, converting the circumference of the vessel into a triangle by means of three stay sutures; he also pointed out the necessity of the use of the finest needles and silk and the maintenance of absolute asepsis. Carrel's method has become the method of choice wherever permanent union is desired and has been extensively used by both experimenters and clinicians; among others, Hubbard, Jensen, Floresco, Watts, Stich, Makkas, Dowman and Lund have used it and reported excellent results.

About two years ago we undertook to perform the operation on the abdominal aorta of cats, with the purpose of acquiring facility in the technic. Of our first series of fifteen animals no statistics were kept. Ether was administered with a cone, and the mortality from ether and from bronchopneumonia following operation was high; thrombosis was frequent.

On the basis of this preliminary experience, we perfected the technic of operation after the manner in which we shall describe it, and as we have used it since. We then undertook a second series of thirty cats, which we operated upon between the dates of January 23, and July 29, 1910. The animals were

anæsthetized by the intratracheal insufflation method. The mortality statistics are as follows:

2 died of thrombosis within 24 hours.
1 died of secondary hemorrhage on 5th day.
1 died of complete rupture on 8th day.
1 died of false aneurism on 33d day.

5 operative deaths.

1 died of general peritonitis on 6th day.
1 died of general peritonitis on 8th day.
1 died of general peritonitis on 23d day.
1 died of gastro-intestinal on 28th day.
1 died of gastro-intestinal on 31st day.

5 deaths from infection and intercurrent disease.

The segments of sutured aorta were saved in the five cases that died of intercurrent disease, preserved in alcohol, and photographed (see Fig. 1). It is worthy of note that in this series there were no ether deaths and no cases of post-operative bronchopneumonia. [1]

The deaths from infection and intercurrent disease were the result of the operating conditions and the housing of the cats.

Of the other twenty animals, twelve were killed August 15, 1910, at the request of Prof. E. H. Nichols of the Department of Surgical Pathology, to supply material for the demonstration of the healing of arteries. Four of the remain-

[1] The apparatus which we used consists of a Wolffe bottle half full of ether; through one stopper passes a glass tube which dips below the surface of the ether and is connected by rubber tubing with the air-pressure tap of the laboratory, and the other connects with a straight metal intratracheal tube. Another piece of tubing is connected with the tubing to and from the bottle so as to pass the air current around it, without taking up any ether vapor. This is long enough to lie in a loop upon the floor. When ether is required, from time to time, the assistant presses upon this loop for a second or two with his foot, forcing the air to bubble through the ether. A mercury bottle is connected on to serve as a safety valve, as described by Ehrenfried: Intrathoracic Insufflation Anæsthesia, Apparatus and Cases, Boston Medical and Surgical Journal, 1911, clxiv, p. 532.

FIG. 1.

Section of healed aortæ taken from cats which died of intercurrent disease (considerably enlarged).

FIG. 2.

End-to-end anastomosis of divided abdominal aorta in a cat; the retroperitoneal space has been opened up, the artery exposed and lifted up on the blunt dissector.

FIG. 3.

The clamps have been applied, and the artery is being divided.

FIG. 4.

The segments are being washed free of blood and clot with sterile salt solution.

FIG. 5.

Trimming off the adventitia.

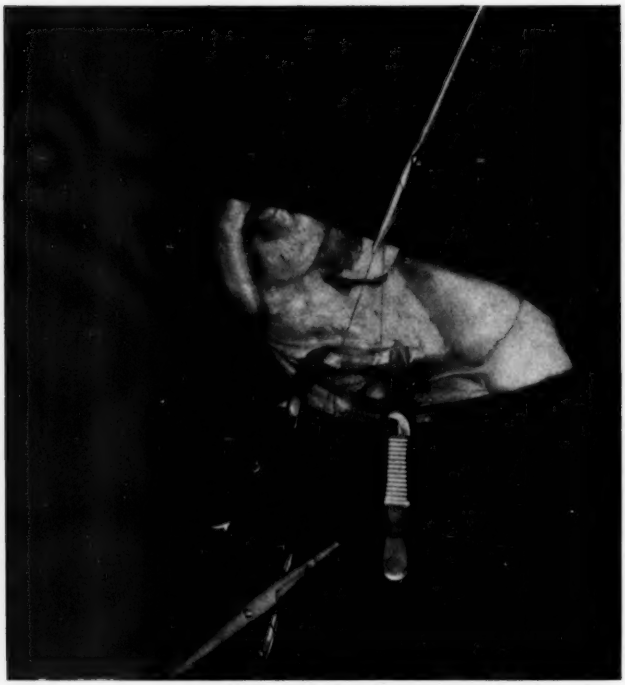
FIG. 6.

Starting the first stay suture.

FIG. 7.

Completing the first stay suture.

FIG. 8.

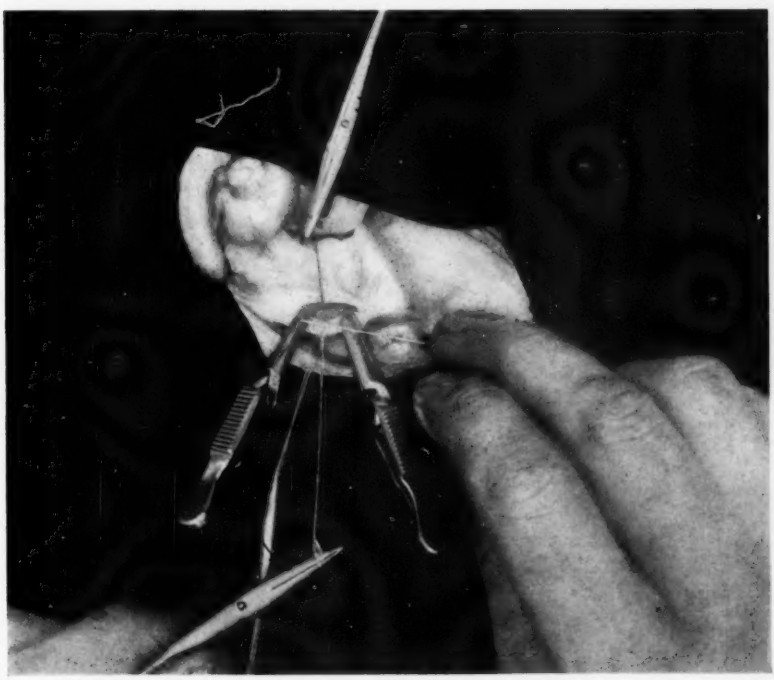


All the stay sutures in place.

FIG. 9.

The stay sutures have been drawn up and tied.

FIG. 10.



Starting the continuous circular stitch. (The needle and silk used for this series of photographs are coarser than those regularly employed.)

ing cats have died since that date, two have been used for other purposes, and two are now living (Aug. 1, 1911).

The kit which we use in operating contains the following instruments:

Six light mosquito hæmostats for use in tying off collaterals, to snap on the ends of the three stay sutures, and on the end of the running suture after it is tied, in starting. Heavy snaps will tear the vessel wall by their weight.

Two vessel clamps. At Carrel's suggestion we use the small old-fashioned "serrefine," with the blades filed smooth, and the tension of the springs weakened until the blades come together flat with the least possible pressure. On large vessels in the human, Crile clamps may become necessary, but the serrefine is preferable because it is lighter and more easily handled. It is a wise precaution in human surgery to apply a Crile clamp some distance proximal to the cut, to provide against the possibility of slipping of the serrefine.

One blunt dissector, to assist in freeing up a sufficient length of vessel for operative purposes. We make use of a straight blunt aneurism needle.

One fine blunt scissors, curved on the side, to trim off adventitia.

Two pair of smooth jeweler's forceps (Boley, MM, filed blunt). These we have found to be the best adapted of any forceps for handling the fine needle.

One medicine dropper and sterile saline solution, for flushing out the segments of artery before sewing.

One bottle of vaseline, in which to sterilize the silk sutures.

Fine Pagenstecher, for tying off small branches cut in freeing the artery. Catgut swells up and interferes with the operation.

Needles, No. 6 Kirby sharps.

Suture material, No. 0000 Chinese silk, untwisted into the three strands of which it is composed. About 18 inches is threaded on the needle, the needle is stuck through a square of card, and the silk is wound about this. Two such cards are enough for an operation; one length will make the three stay sutures, and another will suffice for the continuous suture. On account of the difficulty of threading, it is wise to economize in the suture material. If the needles are allowed to remain for long in the vaseline, they are likely to become brittle.

The ability to perform end-to-end arterial anastomosis comes only as the result of practice, gained upon the living animal. The best subject of experimentation is the cat; it is inexpensive and not hard to care for. The abdominal aorta is easy to get at; it is approximately the size that would be met with in human surgery, slightly larger than the brachial

and slightly smaller than the femoral artery. If the artery thromboses, or if the lumen is sewed up (the commonest mishaps in the beginner), the cat dies.

The animal selected is given no food the night before. For operation it is strapped upon the board, etherized, and the hair clipped from its belly which is washed with soap and water and rinsed with alcohol. Operative asepsis in all its details is essential; gloves, however, are not worn. The operator stands upon the cat's right. An incision is made from one inch below the ensiform to one inch above pubes. A snap is applied to peritoneum and fascia on either side and thrown back. The intestines are taken out and wrapped in a hot towel on the cat's left. (A black silk laparotomy sheet, with one side long for covering the intestines, is a distinct advantage; against it the needle and silk can be readily seen.) The laparotomy sheet is pinned to the edges of the wound by Bachaus towel clamps to prevent exposure of the skin, and to avoid getting hairs into the operative field.

The retroperitoneal space is opened up by blunt dissection, and the aorta is freed for a distance of about three-quarters of an inch between the superior and inferior mesenteric arteries. Occasionally one or two posterior-lateral branches will have to be tied off; double snap with mosquitoes and tie short with very fine Pagenstecher or silk. Tie off as few branches as possible, because the ties get in the way, and because if the branches which supply the cord are cut the cat dies within twenty-four hours with paralysis of the hind legs. Lift up the vessel on the blunt dissector, apply the clamps, perpendicularly, about one-half inch apart, and cut between. Gently wash out the segments of vessel with salt solution in the medicine dropper, and then apply a little warm vaseline to the cut edges with the blunt dissector. Trim off any redundant adventitia or any connective tissue that might get in the way when suturing.

The three stay sutures are now placed at points equidistant about the circumference of the artery, one stitch being exactly posterior, corresponding to the tips of the clamps. The needle

is passed directly through the vessel wall of the proximal segment, including the intima, and is passed back (from within outward) through the distal segment at the corresponding point. If there is any difficulty, the vessel wall may be grasped by the forceps, which have been dipped in vaseline. The stay is not tied, but its ends are left long, and grasped by a mosquito snap. When the last one has been placed, they are all gently drawn up so as to approximate the cut edges of the artery. While the assistant holds two taut, the operator ties the third, snugly, using a surgeon's knot to prevent slipping. The other two are tied in turn; the tied ends of all are left long and snapped with mosquitoes. The ends of the posterior stay should come out on the cat's left.

Everything is now ready for the application of the continuous suture. The clamp handles are directed to the operator, and the first stitch is applied just anterior to the posterior stay suture. A tie is made to start from; its end is left long, and is snapped by the mosquito on the posterior stay. The operator holds the stay suture toward which he is sewing in his left hand, while his assistant holds the stay from which he is sewing, applying enough pull so as to keep the section which is being sewed on the stretch. The third stay, which lies beneath, is slackened up and relieved of the weight of its snap, otherwise the under wall of the artery might be pulled up against the anterior, and the two sewn together. The assistant pulls up with his right hand the slack of the running suture, after each stitch is passed, so as to evert the edges and bring intima to intima. (If the operator prefers to sew away from, rather than toward himself, he ties the posterior stay so that the ends come out on his side, and starts the running suture just anterior to it. In this case the assistant, with his right hand across the table, will hold the two stays, and the surgeon will pull up his own slack.) About six stitches usually suffice for each of the three sections.

The first section being completed, the assistant takes the stay which the operator was holding, the operator picks up the next one, the handles of the clamps are directed to the

side of the assistant, so as to expose the next section, and the suture is continued. When this section is completed, the operator cuts close the stay which the assistant is holding, which is no longer needed. The assistant then passes the long end and the posterior stay, which are snapped together, under the artery. The clamp handles are directed back to the side of the assistant, so as to bring the third section into view. The suture is continued, the operator taking the stay which was passed under, and the assistant the other. This section being completed, the ends of the running suture are tied to each other and cut. The stays are cut and the clamps removed, the distal one first.

There is practically always leakage of blood in some amount, usually through the stay holes, which have been stretched by the pull upon the stay sutures. If the anastomosis is otherwise competent, this ooze will stop in a half minute, some loose gauze being applied over the site of operation. If more than gentle pressure is applied on the gauze, a thrombus is apt to form within the artery. Where there is no leakage, there is probably thrombosis, and the pulsation of the vessel will have disappeared below the anastomosis. In this case the thrombus may sometimes be broken up and sent along by massaging and "milking" the artery. If the artery "spurts" through one hole, where a stitch has cut through, for instance, the clamps may be reapplied and the hole sewed over, with some show of success. In case there is more than one tear, the anastomosis had better be cut out and performed over again.

The intestines are replaced, and the peritoneum and fascia of the abdominal wall are sewed up together with a running buttonhole stitch of Pagenstecher, and the skin likewise. No dressing is applied. The entire operation should take thirty-five minutes or less; the clamps should not be on longer than fifteen minutes.

The advantage of being prepared to apply this technic to human traumatic surgery is suggested by the following case, which we report through the courtesy of Dr. L. R. G. Crandon,

Assistant Visiting Surgeon, Boston City Hospital, who invited one of us to assist him in the treatment thereof. [2]

T. G., Syrian, was brought to the Relief Station of the Boston City Hospital at 4.30 P.M., April 23, 1911, by a police ambulance, with the story that he had been stabbed in the left groin. He was conscious, restless and pale, pulse 80, of small volume and low tension.

Just below Poupart's ligament on the left was a narrow, somewhat pouting, clean-cut slit in the skin about three-quarters inch long, running nearly transversely. There was considerable blood on the thigh and the clothes covering the thigh. About the wound was some swelling. No pulsation in the femoral artery or its branches below this point was made out.

The thigh was cleaned and shaved. On the passing of a director into the wound, to ascertain where to introduce a wick, active arterial hemorrhage ensued. The wound was packed, and a sterile dressing was applied with pressure. Heaters and blankets were ordered, and salt solution administered by rectum.

Patient was cold, restless, and weak for two or three hours, but then became more quiet, stronger, and warmer. There was no return of pulsation in the branches of the femoral artery. Operation was advised and accepted.

Operation, Drs. Crandon and Ehrenfried: Under ether an incision was made above and parallel to Poupart's ligament. The external iliac artery was found and a Crile clamp applied. An incision five inches long was made over and parallel to the femoral artery, the region of the punctured wound was laid open, and the dissection carried down to the femoral artery. This was found completely severed, though the ends were held together beneath by some strands of uncut adventitia. The surrounding tissues were infiltrated with blood-clot. The vein and nerve were intact.

Crile clamps were applied to the artery, the adventitia trimmed away, and the ends sewed together by the technic just described. The clamps were taken off, and then the clamp on the iliac artery was removed. There was some oozing of blood from the anastomosis, which ceased in two minutes under light pressure. Pulsation was readily felt beyond the suture.

---

[2] We are indebted to Dr. Paul Thorndike, Surgeon-in-Chief, Boston City Hospital, for permission to publish the following record.

The abdominal wound was sewed up in layers, the thigh wound by mass sutures. Sterile dressing was applied. Stimulation, heaters and blankets.

The recovery was rapid and uneventful, despite the weakness of the patient from loss of blood. When seen the next day the left foot was warm, and on the day following pulsation of the dorsalis pedis could be readily made out, and heaters and blankets were discontinued. The temperature and pulse were normal on the fourth day, and remained so. On May 3 the stitches were removed, and on May 7 the patient went home, well except for a small granulating area at the site of the original wound.

We have applied this technic also in one case of transfusion, but without satisfaction. We consider the ordinary methods of transfusion, of which that of Elsberg is undoubtedly the best, more rapid and certain. The chief difficulties to suture in transfusion are the inequality in size of the vessels, their difference in texture, and the possibilities of tension under which the operation is performed. There is no question, however, but that the Carrel method of end-to-end anastomosis has already made for itself an important place in operative surgery.

REFERENCES.

(To the more important articles only.)

Lambert: Account of a New Method of Treating Aneurism, Med. Observations and Inquiries, London, ii, 362, 1764.

Asman: Die Aneurysmata, Groningue, Dissert, 1773. Lauth's "Scriptorum Latinorum de Aneurysmatibus Collectio, etc.," 1785.

Wattmann: Sicheres Heilverfahren bei dem schnell gefährlichen Lufteintritt in die Venen, Wien, Braumüller, 1843.

Nicaise: Des plaies et de la ligature des veines, Paris, Asselin, p. 92, 1872.

Eck: Zur Lehre von der Ligature der Proftader, Militär-Medicinisches J., cxxxi, 1877 (see Stolnikow, 1882).

Hirsch: Suture of Veins and Arteries, 1881, quoted by Clermont, 1901.

Gluck: Naht der Blutgefässe, Arch. f. klin. Chir., xxviii, 547–555, 1882.

Braun: Ueber die seitlichen Verschluss von Venenwunden, Arch. f. klin. Chir., xxviii, 654–672, 1882.

Stolnikow: Die Stellung v. Hepaticarum im Leber u. im Gesamtem Kreislaufe, Pflüger's Arch., xxviii, 255–286, 1882.

V. Horoch: Die Gefässnaht, Allgem. Wiener med. Zeit., xxxiii, 263–264; 279–280, 1888.

Jassinowsky: Die Arteriennaht, Dorpat, Dissert, 1889.

Hahn, Massen, Nenki, u. Pawlow: Die Eck'schen Fistel., Arch. f. exp. Path. u. Pharm., xxxii, 161–211, 1893.

Abbe: The Surgery of the Hand, N. Y. Med. Jour., lix, 33–40, 1894.

Queirolo u. Masini: Ueber die Function des Leber, etc., Moleschott: Untersuchungen zur Naturlehre des Mensch., xv., 225, 1895.

Jaboulay et Briau: Recherches Exp. sur la suture et la greffe arterielles, Lyon Medical, lxxxi, 97–99, 1896; Lyon Medical, lxxxvii, 305, 1898.

Nitze: Gefassnaht, Ctlbltt. f. Chir., xxiv, 1042, 1897.

Murphy: Resection of Arteries and Veins in Continuity; End-to-end Anastomosis, Med. Record, li, 73–88, 1897; Int. med. Kong. (Moskau), v. 359–381, 1897.

V. Karltrew: Eck'sche Fistel, Wien. klin. Woch., xii, 205–206, 1899; Arch. f. exp. Path., xlv, 56–65, 1900.

Payr: Beitrage zur Technik der Blutegefässnaht, Arch. f. klin. Chir., lxii, 67–93, 1900; Langenbeck's Arch., lxiv, 726–740, 1901.

Bouglé: Sutures arterielles, Arch. de méd. exp. et d'anat. path., xiii, 205-224, 1901.

Salomoni: Sutura circulare delle arterie con l'affrontamenta del endothelia, Clinica Chir., No. 4, 1900; Ctrlblat f. Chir., xxviii, 464, 1901.

Clermont: Suture latérale et circulaire des veines, La presse Médicale, ix, 229–233, 1901.

Carrel et Morel: La technique operatoire des anastomoses vasculaires et la transplantation des viscères, Lyon Médical, xcviii, 859–864, 1902; Lyon Medical, xcix, 114–116; 152–153, 1902.

Carrel and Guthrie: Uniterminal and Biterminal Venous Transplantation, Surg. Gyn. and Obst., ii, 266–286, 1906.

Carrel and Guthrie: A New Method of Vascular Anastomosis, XV Congrès Internat. de Méd., Lisbonne, ix, 238–249, 1906.

Carrel: Surgery of the Blood-vessels, Bull. Johns Hopkins Hosp., xviii, 18–28, 1907.

Watts: The Suture of Blood-vessels, Johns Hopkins Hosp. Bull., xviii, 153–179, 1907.

Stich, Makkas, and Dowman: Gefasschirurgie, Beit. z. klin. Chir., liii., 113–160, 1907.

LATERAL VASCULAR ANASTOMOSIS.

AN IMPROVED METHOD.

BY BERTRAM M. BERNHEIM, M.D.,

AND

HARVEY B. STONE, M.D.,

OF BALTIMORE, MD.

(From the Hunterian Laboratory of the Johns Hopkins University.)

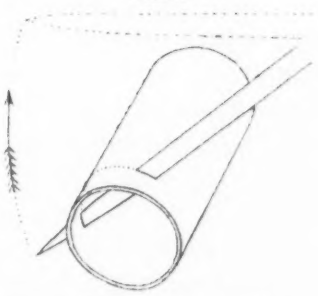
In the course of an experimental study of arteriovenous aneurisms, concerning certain physiological and surgical problems presented by these lesions, the method herein to be described was developed for making lateral anastomoses between blood-vessels. It is published because it seems superior to previous procedures, either for experimental or clinical purposes. A brief description is all that is necessary to supplement the illustrations.

The artery and vein between which the communication is to be established are carefully dissected out, and bull-dog or Crile clamps, rubber-shod, are applied to each vessel at corresponding points. The incision in the artery is made first. A sharp cataract knife, held transverse to the long axis of the vessel, is plunged through the artery in a direction oblique to the horizontal plane in which the vessel lies, so as to form a sector of the lumen with its arc equal to about one-third of the circumference. The knife is thrust in with its cutting edge upward and toward the adjacent vein. The overlying one-third of the artery wall is then divided (Fig. 1). At once the retraction of the longitudinal muscle and elastic fibres causes this transverse incision to gape and become an open ovoid (Fig. 2). Owing to the fact that the knife was entered obliquely and not perpendicularly, this ovoid looks toward the vein and also somewhat upward. The posterior edge of the opening is thus easily accessible for suturing. As soon as the artery is opened all blood is

washed out with salt solution, the adventitia stripped off carefully, and the lumen and other surfaces freely bathed with liquid vaseline. These are precautions common to all vascular surgery—thanks to Carrel—but demand restatement because of their importance. The artery is then protected with vaseline-soaked gauze, and a similar incision, corresponding in size and position, is made in the vein so that it looks toward the artery and upward.

The suture [1] is started by passing the needle through the wall of the artery from without inward, then crossing to the vein and passing here from within outward (Fig. 3).

FIG. 1.



Introduction of knife and direction of incision.

FIG. 2.

Gaping of transverse incision.

When this suture is tied the knot lies outside the vascular lumen (Fig. 4). From this starting point a simple continuous suture is carried around the openings in the two vessels (Figs. 5 and 6), care being taken to avoid purse-stringing. The operation is completed by tying the last suture to the remaining long end of the first tie. No difficulty is experienced in approximating the edges of the incisions, and there is no more tension on the thread than in an end-to-end anastomosis. After completion of the suture, the clamps are removed first from the vein, as in all vascular

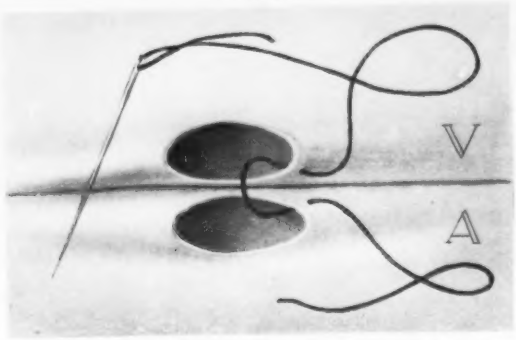
[1] The suture material consists of a straight needle, size 12, ground down, and silk, size .00000, which has been sterilized in vaseline.

surgery. If any marked leakage occurs, the weak spots are reinforced by one or two extra sutures. Then the arterial flow is gradually allowed to go over. During the suturing, intima is not always approximated to intima, but with the establishment of the arterial stream through the anastomosis, the "pull" in opposite directions between the two vessels helps to bring about an accurate approximation.

This method has been employed with great satisfaction a considerable number of times in animals, and was equally simple in execution in the one clinical case in which we have so far had the opportunity to try it. After an interval now of three months, this patient's anastomosis is working splendidly. It is intended to report this case in detail later, with several other clinical cases in which other methods of arteriovenous anastomosis have been used. The rationale of this method has been deduced from a consideration of the cases of arteriovenous aneurism met with in the clinic. Previous laboratory anastomoses have been performed by making longitudinal incisions in the vessels rather than transverse. In the clinical cases following trauma there seems little doubt that the wounds are transverse. A bullet, knife-blade, or other object wounds the adjacent surfaces of artery and vein at the same level. The vessels are held closely together by their investing sheaths, the transverse incisions gape, as illustrated in these sketches, and the gaping lips soon adhere. The method described in this paper is practically a copy of this accidental anastomosis occurring in nature.

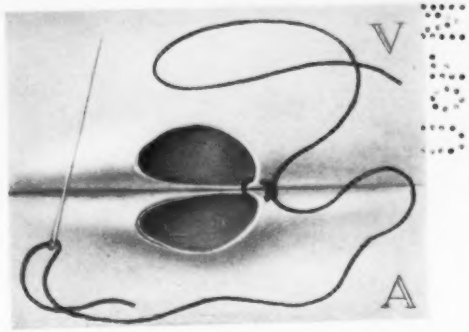
We think that this anastomosis, with a ligation of the vein on the cardiac side of the point of union, offers a much easier and safer method for reversal of the circulation than the present procedure of end-to-end anastomosis of artery and vein, with ligation of the proximal stump of the vein and the distal stump of the artery. When the latter method is used a failure of the anastomosis imperils the knee or elbow, owing to the complete division of the arterial trunk; and as a rule the disease process which leads one to do an

FIG. 3.



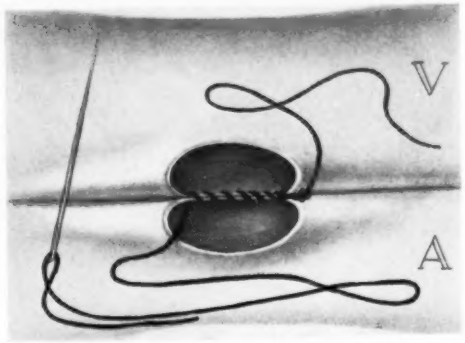
Initial suture placed.

FIG. 4.



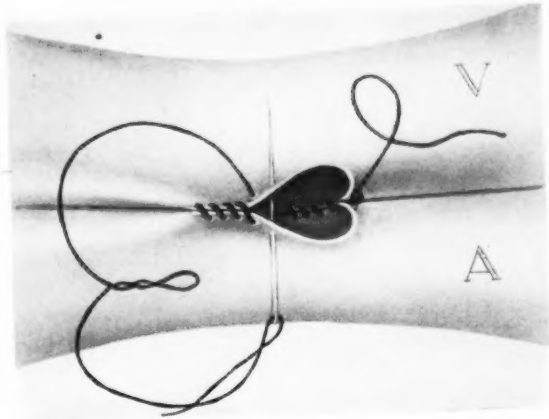
Initial suture tied.

FIG. 5.



Finishing posterior part of continuous suture.

FIG. 6.



Posterior part of suture completed and about half of anterior part placed.

arteriovenous anastomosis is not in itself so advanced as to threaten the larger joints. In the few experiments with the new method in which thrombi developed, they never obliterated the arterial lumen, but were entirely lateral. Moreover, by this procedure, the inflow of blood into a threatened extremity still has whatever arterial channels remain patent, and the venous trunk in addition may be utilized to carry some of the needed excess. It is important to ligate the vein above the anastomosis, to protect the heart from a direct back flow of blood under arterial pressure into its right chamber.

In brief conclusion, this method is presented because of its easy execution, making it superior to the longitudinal incision for experimental work, and because of its safety, making it better than the end-to-end for reversals of the circulation and other clinical conditions.

SOME RECENT MECHANICAL AIDS TO HOLLOW VISCERAL ANASTOMOSIS.

BY C. E. TENNANT, M.D.,

OF DENVER, COLO.

SUTURE methods in hollow visceral anastomosis have, in recent years, become so universal that they may practically be considered the method of choice. This is especially true with the through-and-through suture known as the Connell.

I have found it of advantage in lateral anastomosis to adopt Willard Bartlett's method of using two needles in the one catgut suture, placing the first stitch in the middle of the two approximating edges and approaching both angles early in the operation.

To successfully perform anastomosis with this method, holding clamps are necessary to fix the parts in close apposition during the operation. When two or more clamps are used for this purpose, it requires all the assistant's attention to keep the parts to be approximated in close apposition. More assistants in the field of operation brings added interference, and also increased danger of infection.

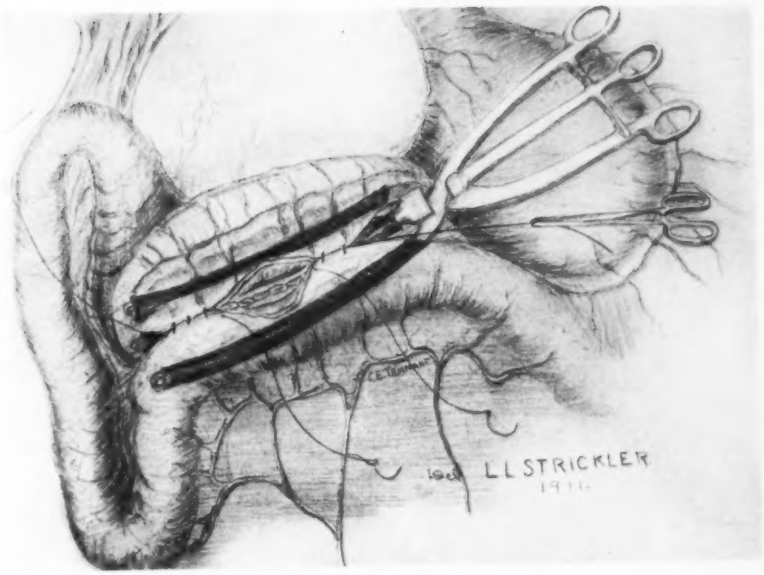
To obviate these objections we have, within the past few years, devised two instruments which we believe materially simplify the technic of visceral anastomosis.

One of these is the three-pronged compound clamp known as the "Roosevelt clamp," which was devised by my assistant, the late Dr. G. F. Roosevelt, and myself some six years ago. This clamp was designed solely for gastro-enterostomies, and with its several modifications is now quite generally in use and accomplishes several purposes.

First: It holds the parts to be anastomosed absolutely fixed in the position in which they have been placed, and no amount of manipulation can disarrange them.

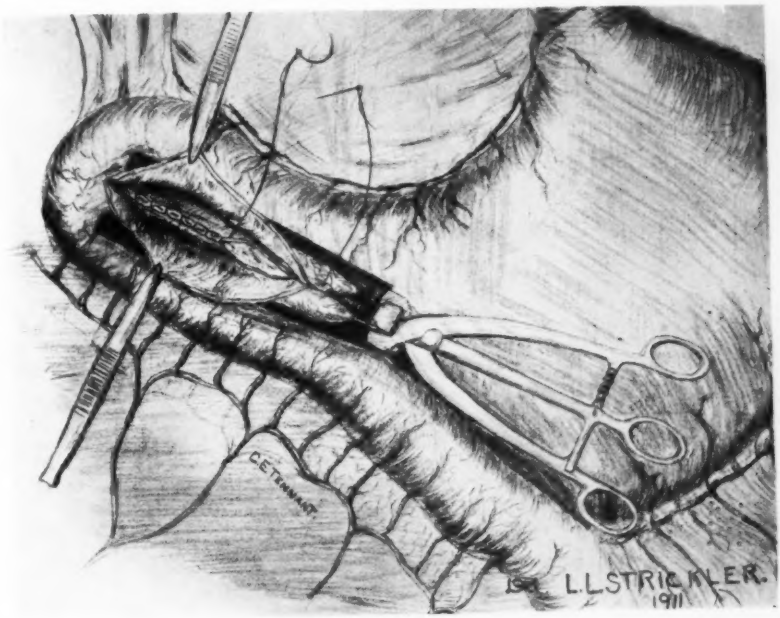
Second: There is no need of the instrument being held.

FIG. 1.



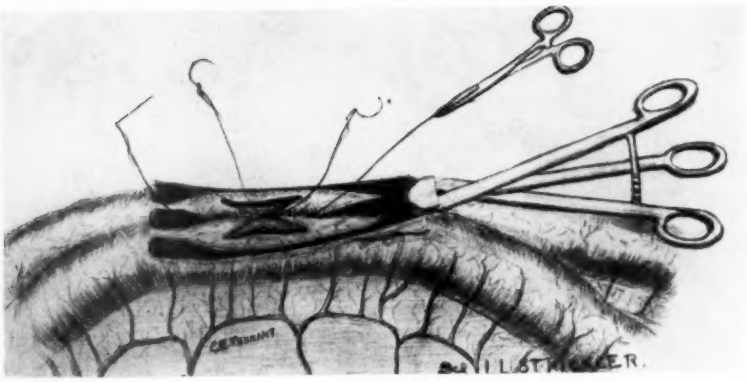
Posterior gastro-enterostomy with the Roosevelt clamp.

FIG. 2.



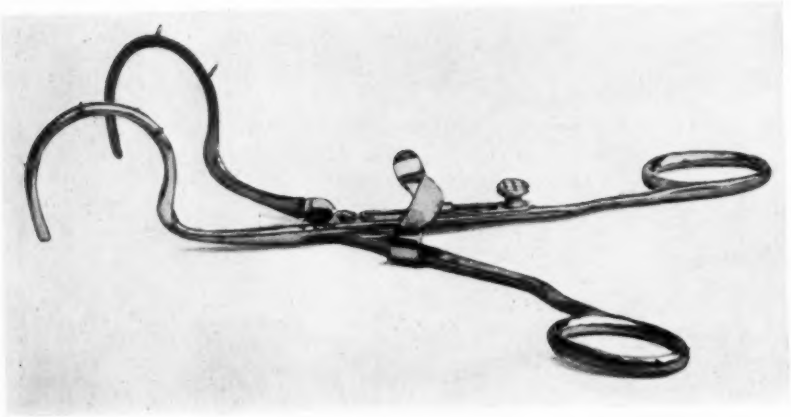
Finney's pyloroplasty with the Roosevelt clamp.

FIG. 3.



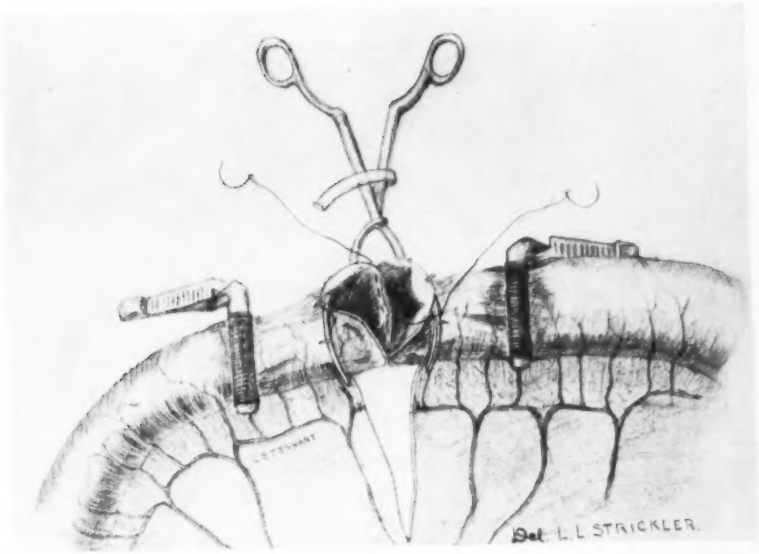
Lateral anastomosis.

FIG. 4.



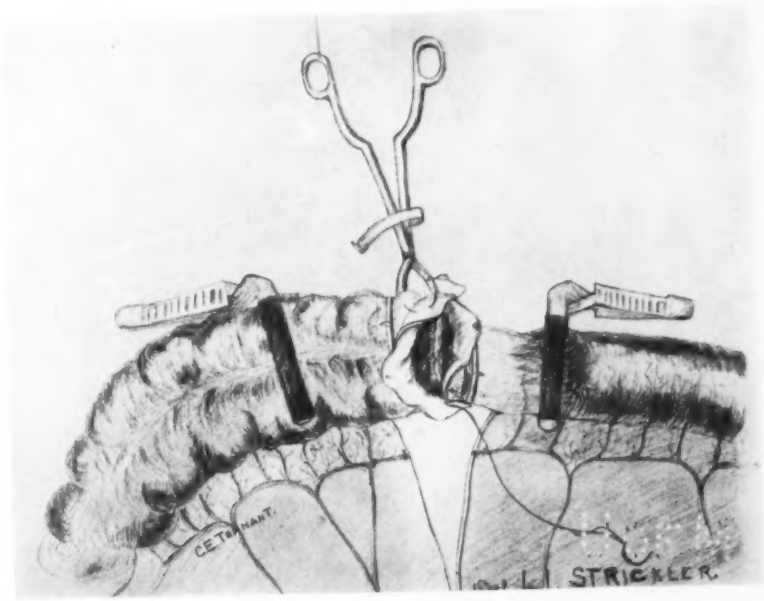
Two-loop clamp for end-to-end intestinal anastomosis.

FIG. 5.



End-to-end suture anastomosis with help of clamp.

FIG. 6.



Anastomosing unequal ends.

since it is heavy enough to lie on the patient's abdomen with the parts fixed in position, while the one assistant has both hands free to aid the operator (Fig. 1).

This clamp is, of course, adapted to either posterior or anterior operations. The same clamp with the straight prong is also extremely practical in the pyloroplasty of Finney (Fig. 2), and in gastric anastomosis after partial gastrectomy.

An imitation of this three-pronged clamp, called the "Lennartz clamp," followed about six months after the Roosevelt. It is a much lighter and smaller instrument, and I have found it especially practical for pyloroplasty and lateral intestinal anastomosis (Fig. 3). It, too, leaves the hands of the assistant free to aid the operator.

The second instrument is that of an end-to-end anastomosis clamp. While the use of end-to-end anastomosis is not practicable in every case, still my experience has been that where this form of anastomosis is made in the ileum and colon with suitable instruments, it can be accomplished in one-half the time consumed by a lateral anastomosis, and if the modern theories of Lane and others regarding the kinks, flexures, and stagnation are tenable, then the end-to-end anastomosis is far more consistent to employ than the lateral. These reasons alone, I believe, are sufficient to justify the more frequent employment of the end-to-end anastomosis when it can safely be accomplished.

The instrument to which I refer, and which I recently devised for this purpose, automatically holds the ends of the severed gut in an open and fixed position while suturing, and it also leaves the assistant's hands free for other work. The instrument is simple in construction and manipulation (Fig. 4).

The method, briefly described, is to pass the two ends of the intestines under the loops of the instrument, the handles of which point away from the operator. The intestine is then impaled on the three pins in their respective loops. When the loops are separated the dangerous mesenteric border is brought well up to the surface, where a curved needle with a long suture (preferably chromicized) is passed through both

ends of the bowel on the opposite side from the operator, and midway between the dome and the mesenteric border (Fig. 5). The suture is continued on around through the mesenteric border and up on the side nearest the operator until the dome is reached. The needle is then transferred to the loose end left for this purpose, where the suture was first commenced, and enters the peritoneal surface including all coats of the bowel.

The intestine is now released from the pins and the suture continued on over the dome, keeping well outside of the three perforations made by the instrument. The two approximated ends of the suture are then tied from the outside. It is surprisingly simple to anastomose the ends of unequal bowel with this instrument (Fig. 6), and the resulting infolding of the smaller gut into the larger is very much similar to the recent Gibson peritoneal invagination method.

The advantages of using this instrument are: (1) the safety of the complete circular suture; (2) the definite care of the dangerous mesenteric zone, and (3) the economy of bowel, since by this method it need be no more than an approximation.

LIGATION OF THE FIRST PORTION OF THE LEFT SUBCLAVIAN ARTERY.

WITH REPORT OF A RECENT SUCCESSFUL CASE.

BY JAMES M. NEFF, M.D.,
OF SPOKANE, WASH.

RECOVERY so rarely follows ligation of the first portion of the left subclavian artery, especially in the presence of severe infection, that I think the following case worthy of record.

CASE REPORT.—Mr. H. W., age twenty-three years, single. In December, 1909, patient first noticed an enlargement of the glands in the left side of the neck.

Patient entered the Deaconess Hospital, Spokane, on February 11, 1910. In left side of neck there was a chain of enlarged lymphatic glands extending from the mastoid process to the clavicle. The centre of the mass was more prominent, tender to pressure, and presented deep fluctuation. There was considerable periadenitis, the glands being adherent to each other and quite immovable. Examination of heart, lungs, and abdomen negative.

Operation, February 12, 1910: An incision was made, extending from the mastoid process downward along the anterior border of the sternomastoid muscle to the middle of the neck, then backward, severing the muscle, and continuing down to the clavicle along its posterior border. The chain of enlarged glands was reached through this incision, and their removal begun from below by clearing the space between the internal jugular vein and the clavicle. The glands and infiltrated gland bearing tissue in this situation was dissected free with some difficulty, but without apparent injury to any of the important structures in the neighborhood. The lower angle of the wound was then tamponed to produce distention of the internal jugular vein, and the dissection of the glands was continued in an upward direction. This was accomplished with a good deal of difficulty, owing to the extensive periadenitis and suppuration in the centre

of the mass. It was finally completed, however, and we were about ready to close the wound, when there was a sudden gush of blood from the lower part of the wound behind the clavicle. The hemorrhage was very profuse and came on without the slightest warning, as we had been working in the upper part of the neck and had not touched the lower portion since the beginning of the operation. The flow of blood was stopped by pressure with the fingers behind the clavicle, and the field cleared by sponging. An examination was then made and it was found that the hemorrhage had come from the subclavian artery just internal to the scalenus anticus muscle. By cautiously moving the fingers inward, the outer border of the small opening in the artery was revealed. A hæmostat was then placed on the vessel in this situation and two more to the inner side of the first, thus closing the opening. The wound in the neck was now closed in the usual manner, after uniting the cut ends of the sternomastoid muscle with catgut sutures. A drainage tube was placed in the upper part of the wound on account of the secondary infection, and the hæmostats were allowed to protrude through the lower angle of the incision.

Patient was returned to bed in fair condition, with pulse 110 and temperature 100.8° F.

On February 14, 48 hours after operation, the hæmostats were carefully removed and two moderately firm gauze packings were inserted, one upon the other behind the clavicle and down to the artery. No bleeding occurred immediately after the removal of the forceps, but three hours later the patient had a very severe hemorrhage which stopped spontaneously. The outer packing was then removed and replaced by a firmer one, which was held in position by a tight adhesive plaster drawn across the wound and over the shoulder. After the hemorrhage the patient was anæmic and pulse went up to 118. On February 18, four days later, there having been no hemorrhage in the interval, the outer packing was removed, but the one next to the artery left undisturbed. The wound looked well, though there was slight purulent discharge from the upper part through the drainage tube. Pulse 112, temperature 101.6° F. Early the next morning, 11 hours after the last dressing, patient had another very severe hemorrhage. On the 19th he became delirious and on the 20th had two more hemorrhages. From this

date until the 25th, there were no hemorrhages, his pulse went down to 98, temperature nearly to normal, and we were greatly encouraged about his condition. On February 25 another severe hemorrhage occurred, and between this date and March 4, a period of seven days, he had fourteen hemorrhages of greater or less severity. During this time the temperature ranged from 99.6° to 101° F. On February 27 cultures were taken by Dr. Frank Hinman from the pus in the drainage tube for the purpose of making autogenous vaccines. On this date, slight œdema of the arm and weakening of the radial pulse were noted, the result of long-continued pressure on the subclavian artery. On March 3 Dr. Hinman injected 150,000,000 bacteria in right arm. On March 4, condition of patient became so grave that we decided that his only hope lay in the ligation of the first division of the subclavian. This procedure had been considered several times before, but as we had been unable to find in the literature the report of a single successful case of ligation of the first portion in the presence of sepsis, we had looked upon the operation as a last resort. At the time we decided to ligate the artery our patient had a temperature of 103.6° F., pulse 160, and he was delirious from anæmia and sepsis. For five hours before the operation we kept up continuous digital compression of the artery, as the hemorrhage would recur whenever the pressure was released.

Operation, March 4, 1910, 7.30 P.M.

Before beginning the operation an intravenous saline transfusion was given in the median basilic vein of the right arm.

An incision was made along the upper border of the clavicle, from the outer third to the sternoclavicular articulation and then upward for 2½ inches through the old incision along the posterior border of the sternomastoid. An abscess cavity containing several drachms of foul-smelling pus was found beneath the latter muscle. The clavicle was divided with bone-cutting forceps 1¼ inches from the sternum, and the ends retracted in a downward direction, thus giving good access to the subclavian space. Up to this time pressure on the subclavian had been maintained, but when all was in readiness the pressure was released and the packing removed. A gush of blood immediately followed but was at once controlled by direct pressure with the fingers, followed by the application of hæmostats to the opening

in the artery. The scalenus anticus was next divided, the thyroid axis and vertebral artery recognized, and the subclavian dissected free in a downward direction from the surrounding structures. The dissection was particularly difficult because of the previous operation and the infection of the field, which had caused a matting together of all the tissues. By careful work, however, the subclavian and innominate veins were isolated and drawn forward and the thoracic duct recognized and separated from the artery. After the vessel was completely isolated, two attempts were made to ligate it in the upper portion of the first division, but both ligatures cut through the outer coats and had to be removed. Finally three-quarters of an inch above the aorta the wall was strong enough to tolerate a ligature, and a double strand of medium sized silk on an aneurism needle was passed from below upward, behind, and around the vessel. This double ligature was tied in a simple square knot (not the Ballance and Edmunds stay knot) just tight enough to occlude the artery and stop pulsation. A hæmostat was then clamped on the vessel about one-quarter inch distal to the ligature. Another double silk ligature was tied around the artery distal to the opening in its wall and a second hæmostat applied proximal to it. The thyroid axis, vertebral, and internal mammary arteries were then ligated with silk and the forceps removed from the wound in the subclavian. A loose packing of iodoform gauze was placed in the deep cavity behind the clavicle, the ends of the clavicle united with aluminum bronze wire, and the external wound closed with interrupted silkworm gut sutures.

When patient was returned from the operating room, his pulse was 140 and temperature 103° F. For ten days after operation the blood-pressure was kept below 112 mm. of mercury by diminishing the amount of ingested liquids and giving spirits of nitroglycerin whenever it reached that point.

Restlessness was controlled by hypodermics of morphine. Five days after operation the autogenous vaccines were again given and repeated every three or four days thereafter. The temperature ranged from 100.2° F. to 104.2° F. and pulse 120 to 150, until March 19, fifteen days from time of operation, after which both gradually went down to normal. Patient continued delirious at intervals until March 15. The hæmostats were removed from the ligated vessels on March 13, nine days after

operation. On March 13, he developed a right-sided pleurisy and cough, with yellowish expectoration. His temperature was 103° F. to 104° F. and pulse 130 to 140 for a few days, but the trouble entirely subsided within a week. On March 19 the ends of the clavicle, which had become separated, were reunited. He was allowed out of bed for the first time on March 20, sixteen days after operation. The wound, which was infected at the time of operation, continued to suppurate until the patient left the hospital on April 2, although it filled rapidly with granulations and was about flush with the clavicle at the time of his discharge.

The radial pulse disappeared when the artery was ligated and has not returned to date, sixteen months after operation.

The peripheral circulation remained good after the ligation and the hand and arm were warm at all times.

Marked atrophy of the arm, forearm, and hand took place during the two or three months following operation, and there was great weakness of all the muscles of the left upper extremity from shoulder to fingers.

Tactile and pain sense were abolished over the lower third of the forearm, hand, wrist, and fingers for four months, and muscular sense in the hand was greatly impaired for the same time.

As a result of almost constant exercise, frequent massage, and faradic electricity to the weakened and atrophied muscles, the muscular power is now about normal and the muscles have regained their normal volume and tone. There still remains, however, slight impairment of tactile sense in the tips of the fingers. The general health of the patient at the present time is perfect, weight up to normal, and he is able to attend to his regular business affairs.

This case presents a number of interesting features. First: The manner in which the artery was injured. We had finished our dissection in the subclavian space, apparently without injury to any important structure, and in fact had completed the entire operation when the hemorrhage suddenly occurred without apparent cause. The only possible explanation was a weakening of the vessel wall produced during the separation of the adherent glands and infiltrated gland-bearing tissue.

Second: The youthfulness of the patient. This was undoubtedly an important factor in the successful outcome of the case, as statistics show that the large percentage of recoveries after ligations of the great vessels occur in young individuals, due probably to the greater elasticity of the vessels. It is well known that healthy elastic vessels tolerate ligation better and are less likely to cut through than diseased ones. Collateral circulation is also more readily developed in them, as they offer less resistance and distend more easily.

Third: The favorable influence of the autogenous vaccines. So far as can be learned from a study of the literature this is the first successful case of ligation of the first surgical division of the left subclavian artery, where the operation was performed in an infected field and the wound continued to suppurate afterward. In view of this fact we are inclined to attribute to the use of the vaccines a part, at least, of the credit for the recovery of the patient. The culture from the pus taken by Dr. Hinman on February 27 showed the *Staphlylococcus aureus* and *albus* and the *Streptococcus*. A vaccine was made from each of these organisms after the method of Wright, mixed and counted. From March 3 to April 5 injections of the vaccines, ranging in amount from 150,000,000 to 550,000,000 bacteria, were given every two or three days.

Fourth: The application of hæmostats distal to the proximal ligatures and proximal to the distal ligatures, and the retention of them in place for nine days after the operation. Just how much this had to do with the favorable result we are not prepared to say, as we are unable to find in the literature any record of a case similarly treated. The flexible bladed forceps were placed close to the ligatures and probably took some of the strain from the ligated portion, as the silk was tied just firm enough to obliterate pulsation and not sufficiently tight to injure the intima.

Fifth: The influence of long-continued pressure on the artery before operation upon the development of efficient collateral circulation. This was probably another important

factor in bringing about a successful result. It will be noticed in the record that from the time we removed the hæmostats, two days after the first operation, until the date of the ligation, a period of eighteen days, there was practically continuous pressure on the vessel. This pressure was exerted through the gauze packing most of the time and was sufficient to cause œdema of the arm on February 27, and weakening of the radial pulse on February 28. This continuous pressure undoubtedly had much to do with the development of the collateral circulation prior to the ligation of the artery. The only evidence of severe disturbance of nutrition in the extremity after the ligation was a very small painless perforating ulcer in the tip of the middle finger. This came on about three weeks after operation, perforated to the bone, and then promptly healed.

A few words here in regard to the surgical anatomy[1] of the subclavian artery may not be out of place. The relations of the second and third portions are the same on both sides, while those of the first division differ on the right and left. This is due to the fact that the right subclavian is given off from the innominate and the left arises direct from the aorta. The right vessel is three inches long, and arises just behind the right sternoclavicular joint. The first portion, internal to the inner border of the scalenus anticus, has in front of it the right vagus nerve, the cardiac branches of the vagus and sympathetic, and the internal jugular and vertebral veins. Behind it are the recurrent laryngeal nerve and the apex of the right pleura. The left subclavian artery is four inches long, and arises from the aorta behind the lower part of the manubrium sterni. The first portion, internal to the scalenus anticus, is in relation anteriorly with the following structures: The left vagus nerve, the left superior cardiac branch of the sympathetic, the left inferior cardiac branch of the vagus, the left phrenic, and the left common carotid artery. It is crossed obliquely by the left innominate vein above and is overlapped on the left side by the left lung and pleura. Posteriorly it is in relation on the inner side with the left margin

of the œsophagus and the thoracic duct and on the outer side with the pleura. Internally it is in relation from below upward with the trachea, the left recurrent laryngeal nerve, the œsophagus, and thoracic duct. Externally it is closely invested by the left pleura.

Collateral Circulation.—When the artery is ligated in its first portion distal to the origins of the vertebral, thyroid axis, and internal mammary arteries, the collateral circulation takes place through the following anastomoses:

1. Branches of the suprascapular (from thyroid axis) with the superior thoracic (from first part of axillary).

2. Between the internal mammary and the superior thoracic.

3. Between the suprascapular and the acromiothoracic (from second part of axillary).

4. Between the internal mammary and the acromiothoracic.

5. Between the posterior scapular branch of the transverse cervical (from the thyroid axis) and the subscapular (from third part of axillary).

6. Between the suprascapular and subscapular.

7. Between the acromial branches of the suprascapular and the posterior circumflex (from third part of axillary).

8. Between the intercostals and the pectoral branch of the acromiothoracic.

9. Between the intercostals and the long thoracic (from second part of axillary).

If the ligature be applied to the subclavian proximal to the origins of the vertebral, thyroid axis, and internal mammary arteries, the collateral circulation will develop as follows:

1. Between the intercostals and the pectoral branch of the acromiothoracic.

2. Between the intercostals and the long thoracic.

3. Between the lateral branches of the intercostals and the subscapular.

4. Between the aortic intercostals and the anterior intercostal branches of the internal mammary.

5. Between the inferior phrenic (from the aorta) and the musculophrenic branch of the internal mammary.

6. Between the deep epigastric (from the external iliac) and the superior epigastric (from the internal mammary).

7. Between the deep branch of the princeps cervicis (from the occipital artery) and the superior intercostal (from first portion of subclavian on left side and the second portion on the right side).

8. Between the occipital (from the external carotid) and the ascending cervical branch of the inferior thyroid (from thyroid axis).

9. Between the ascending pharyngeal (from the external carotid) and the ascending cervical branch of the inferior thyroid.

10. Between the œsophageal branches of the thoracic aorta and the œsophageal branches of the inferior thyroid.

11. Between the superior thyroid (from the external carotid) and ascending terminal branches of the inferior thyroid.

12. Between the inferior thyroid of the opposite side and the inferior thyroid of the same side.

13. Between the arteria princeps cervicis (from the occipital) and the superficial cervical artery (from the transverse cervical).

14. Between the dorsal branches of the intercostals and the posterior scapular branch of the transverse cervical.

15. Between the occipital artery (from the external carotid) and the muscular branches of the second part of the vertebral.

16. Between the princeps cervicis and the anastomotic branches of the third part of the vertebral.

17. Between the right and left vertebral arteries through the circle of Willis.

It will thus be seen that the opportunities for the development of collateral circulation are numerous, whether the ligature is applied proximal or distal to the origin of the branches. This fact explains why gangrene so seldom follows ligation of the artery.

An important factor in the establishment of collateral circulation after ligation of the great vessels is the increased pressure in the general circulation and the lowered pressure in the segment beyond the ligature.

The time of return of the radial pulse varies greatly in different cases, depending upon the number and efficiency of the collaterals. In some cases, however, where the circulation continues perfect, so far as nutrition is concerned, the radial pulse never returns. In one case reported by Koch it was felt immediately after the vessel was tied, in two cases in the first twenty-four hours, and in twelve cases during the first five days. In the remainder the pulse returned later, in one after six months.

In most of the cases, the temperature of the ligated side is lower than that of the other, but in a few it has been higher.

Sir Astley Cooper attempted to tie the first portion of the left subclavian artery in 1809, but abandoned the operation, thinking that he had injured the thoracic duct. The first ligation of the vessel on record was done by Colles in 1815.[2] The patient died. Dr. J. Kearney Rogers of New York ligated the first portion on the left side in 1846.[3] His patient died of hemorrhage on the sixteenth day. Halsted, of Baltimore, in 1892[4] successfully tied the first portion on the left side for aneurism of the subclavian and axillary arteries, and in 1898 performed another successful ligation while removing a tumor from the subclavian region, Dr. John C. DaCosta ligated the vessel twice, with recovery of both patients, and Nassau, of Philadelphia, successfully ligated it in its first division for aneurism of the third portion. B. F. Curtis in 1897 and Allingham in 1899 both reported successful cases.

The mortality statistics of ligation of the subclavian vary greatly, depending upon whether the cases were tabulated before or after the aseptic era. Thus Polland's statistics show that in the pre-antiseptic era ligation of the vessel, regardless of the portion ligated, gave a mortality of 70 per cent. The best results were obtained in the third portion. The first division was ligated eleven times with eleven deaths. Since

the beginning of the antiseptic era, however, the mortality has been only 22 per cent., irrespective of the portion ligated. H. Lilienthal[5] secured notes on 89 cases of ligation of the subclavian for aneurism before 1890. The mortality rate from all causes for the entire number, irrespective of the portion of artery ligated, was 52.8 per cent. He further states that the mortality of ligation of the first portion of the vessel on the right side has fallen from 75 per cent. in 1890 to 16 per cent. in 1906. He attributes this diminution in mortality to the use of the stay knot of Ballance and Edmunds.

According to Koenig, the first portion of the right subclavian has been ligated 20 times with one recovery, death being due to secondary hemorrhage in the great majority of cases. Asthurst collected 19 cases of ligation of the first portion with a mortality of 100 per cent, one patient dying on the thirty-sixth day. Sir J. C. Erickson gives a table of 14 cases operated on with 14 deaths. Deaver, in 1889, reported 16 cases with 13 deaths, and Bryant, 21 cases with 19 deaths. J. D. Bryant[6] in his "Operative Surgery" states that the subclavian artery has been ligated in its three divisions 250 times with 134 deaths. Jacobstahl[7] collected 47 cases of proximal ligations for aneurism, of which eight were of the first division. Seven of the eight cases died, five from hemorrhage, one from exhaustion, and one from rupture of the sac. Of the eighteen cases of ligation of the first portion collected by Wyeth all ended fatally. In five of these, the common carotid was also tied. Death was due in most cases to hemorrhage from the distal segment of the artery.

Causes of Death.—By far the most frequent cause of death is secondary hemorrhage, which may occur at any time from the end of the first week to the sixtieth day. If the wound continues to discharge after the operation, the patient is not out of danger until the sinus closes, no matter how long it may remain open. This is doubtless due to the fact that the sinus is kept open by the ligature material acting as a foreign body, which therefore maintains an open tract from the artery at the point of ligation to the surface of the body. Furthermore, as this sinus is always infected, we have the

added danger of sepsis, with possible ulceration of the ligature into the lumen of the artery and consequent fatal hemorrhage.

Secondary hemorrhage is probably also favored by tying the ligature too tight and thus injuring the intima. Halsted thinks that if the coats of the artery were not divided but merely compressed by the ligature, and if absorbable material were used instead of silk, the mortality would be much lower. H. Gilbert Barling [8] shares this opinion with Halsted. J. A. Blake [9] also thinks that there would be little danger of late hemorrhage if the ligature did not injure the intima. A ligature tied with the ordinary knot is more likely to ulcerate through the wall at the position of the knot than one tied after the method of Ballance and Edmunds. This method consists of passing two separate strands of ligature material around the vessel, tying each in a simple knot in the same direction, and then, by using the two strands on each side as one, completing the square knot.

A diseased condition of the vessel wall is another very important cause of secondary hemorrhage, and is one of the chief factors concerned in the late bleeding that occurs after the ligation of the great vessels for aneurism. Arteriosclerosis, syphilis, and local sepsis are the principal lesions which we meet with in this connection. If, on the other hand, the walls of the artery are healthy and the vessel elastic, there is less tendency for the ligature to cut through. This is due to the fact that the local pressure is better resisted and the collateral circulation develops more rapidly than in diseased vessels.

The primary and determining cause of secondary hemorrhage, however, is the enormous intravascular pressure which is constantly pounding against the blind end of the vessel. Naturally, then, the nearer the ligature to the heart the greater the pressure and the more likely it is to cut through (Oberst).

Secondary hemorrhage may take place either from the proximal or distal end when the vessel is ligated in continuity. Oberst [10] states that it is usually the distal end which bleeds after the ligature cuts through, the central end often being

thrombosed. It would seem, therefore, that the application of two separate ligatures, a short distance apart, would give greater security against this accident when the vessel is ligated in continuity.

Sepsis is another frequent cause of death, as is shown by the statistics of the pre-antiseptic era. It may prove fatal: first, by inducing a general septicæmia; second, by setting up a diffuse mediastinitis; third, by causing a septic thrombus in the ligated vessel, with septic emboli in different parts of the body; or, fourth, by favoring ulceration of the ligature into the lumen of the vessel and thus causing secondary hemorrhage. Oberst says that if sepsis is present, the patient is doomed to die and that attempts at secondary ligation in an infected field are almost always futile. Sepsis, the result of gangrene of the limb, may also figure as a cause of death.

Shock, pneumonia, pulmonary embolus, cerebral embolus, air embolism from injury of the internal jugular, subclavian, or innominate veins, and injury to the pleura and thoracic duct, have all been mentioned as causes of death after ligation of the first portion of the subclavian artery.

It is a remarkable fact that gangrene rarely follows ligation of the subclavian artery, and is accounted for by the abundant anastomoses and numerous collaterals on both sides of the ligated portion. Cases have been reported, however, where gangrene of the entire upper extremity followed the operation, and others where the fingers or portions of the hand have become necrotic. E. Wolff [11] reports from the clinic of Dr. E. Lexar 12 cases of ligation of the subclavian artery (part not specified) with two cases of gangrene. One of these was a traumatic aneurism of the subclavian and the other an aneurism of the radial artery, where the brachial was first ligated and later the subclavian.

Rotter collected seven cases of ligation of the subclavian artery, in one of which the vein was also tied. In none of these did necrosis develop. Jacobstahl quotes Poiret's statistics of surgically treated aneurisms of the innominate artery. There were 72 cases treated as follows: first, ligation of the right subclavian or axillary—five times with recovery in all

cases; second, ligation of the right subclavian or axillary and right common carotid—65 times with recovery in 37. Among the 42 cases that recovered there was one of gangrene of the right arm, 2.4 per cent. The older statistics of Koch give 212 ligations of the subclavian above the clavicle, or of the innominate, with three cases of gangrene of the arm and four of necrosis of the hand or separate fingers. In 45 ligations under the clavicle there were no cases of gangrene.

According to Von Bergmann, in 90 ligations of the subclavian artery for gunshot wounds (1877) there were no cases of gangrene of the arm, and in only three was there necrosis of the fingers. In the latter cases the injury was very severe.

Five cases of ligation of the subclavian artery with five recoveries have been reported during the past five years.[5 9 12 13 14] All of these operations were done for aneurism of the right subclavian or innominate arteries, and all of the patients were over forty years of age; one was sixty-three. In one case, the circulation of the arm was poor at first, but improved soon after the operation, and in another there was slight cyanosis for a time. There was no necrosis in any of the cases. Chromic catgut was the ligature material used in three of the cases, and silk in one.

REFERENCES.

[1] Cunningham's Anatomy.
[2] Colles: Edinburgh Med. and Surg. Journal, 1815, xi, 1.
[3] Dennis's System of Surgery.
[4] Halsted: Johns Hopkins Bulletin, 1892, iii, 93.
[5] Lilienthal, H.: Journal of A. M. A., 1906, xlvi, 872.
[6] Bryant, J. D.: Operative Surgery.
[7] Jacobstahl: Deut. Zeitschr. f. Chir., 1903, lxviii.
[8] Barling, H. Gilbert: Birmingham Lancet, 1905, xi, 823.
[9] Blake, J. A.: Annals of Surgery, 1906, xliii, 919.
[10] Oberst: Beit. z. klin. Chir., 1904, xli, 466.
[11] Wolff, E.: Beitr. z. klin. Chir., 1908, lviii, 762.
[12] Da Costa, J. C.: Journal of Surgery, Gynæcology and Obstetrics, 1910, x, 620.
[13] Prince, E. M.: Alabama Med. Journal, 1908, ix, 21, 473.
[14] Pearse, H. E.: Medical Brief, St. Louis, 1908, xxxvi, 189.

FIBRO-EPITHELIAL TUMORS OF THE MAMMARY GLAND.

BY ROBERT B. GREENOUGH, M.D.,

OF BOSTON, MASS.,

Surgeon to Out-Patients, Massachusetts General Hospital; Assistant Professor of Surgery, Harvard Medical School,

AND

CHANNING C. SIMMONS, M.D.,

Surgeon to Out-Patients, Massachusetts General Hospital; Assistant in Surgery, Harvard Medical School.

THIS communication is based upon the study of 44 breast tumors which were obtained from the operating rooms and laboratories of the Massachusetts General Hospital.[1] Microscopic sections of each tumor were available for study, and the gross specimens in many cases were preserved or photographed. The clinical data were obtained from the hospital records and from personal communications from the surgeons in charge. The pathological condition was made the prime consideration in dividing and classifying the cases in different groups, but the clinical data for each group have been collected and analyzed to distinguish so far as possible the symptomatology and differential diagnosis of the different forms of tumors.

The classification of breast tumors published by Dr. J. Collins Warren[2] makes of the fibro-epithelial tumors of the

[1] The writers would here express their thanks to Drs. C. B. Porter, J. C. Warren, H. H. A. Beach, A. T. Cabot, J. W. Elliot, M. H. Richardson, F. B. Harrington, S. J. Mixter, W. M. Conant, C. L. Scudder, J. G. Mumford, F. G. Balch, Hugh Williams, Hugh Cabot, Lincoln Davis, and Dr. A. P. Torrey for the use of their material, and to Drs. W. F. Whitney and J. Homer Wright for assistance in collection of specimens and much valuable criticism.

[2] J. Collins Warren: Jour. Amer. Med. Assn., July 15, 1905. *Fibro-Epithelial Tumors.*—(*a*) Fibrous type: 1, periductal fibroma; 2, periductal myxoma; 3, periductal sarcoma. (*b*) Epithelial type: 1, fibrocystadenoma; 2, papillary cystadenoma.

mammary gland two main types, (*a*) fibrous, and (*b*) epithelial, according to the preponderance of one or the other tissue. This distinction is important from a clinical point of view on account of the greater predisposition to malignancy which is shown by tumors of the epithelial type. The tumors of the fibrous type are those in which the connective tissue preponderates over the epithelium. They are mixed tumors, like the other intrinsic tumors of the mammary gland, and contain both epithelial ducts and fibrous stroma, but because of the preponderance of the fibrous stroma and its similarity to, and probably origin from, the fibrous tissue immediately surrounding the ducts of the gland, they have been called by Dr. Warren "periductal tumors." In the Warren classification they are divided, according to the cell characteristics of this fibrous tissue, into three groups: periductal fibroma, periductal myxoma, and periductal sarcoma. It is the tumors of these three groups, together with those of the fibrocystadenoma group of the epithelial type that form the basis of this communication.

PERIDUCTAL FIBROMA.

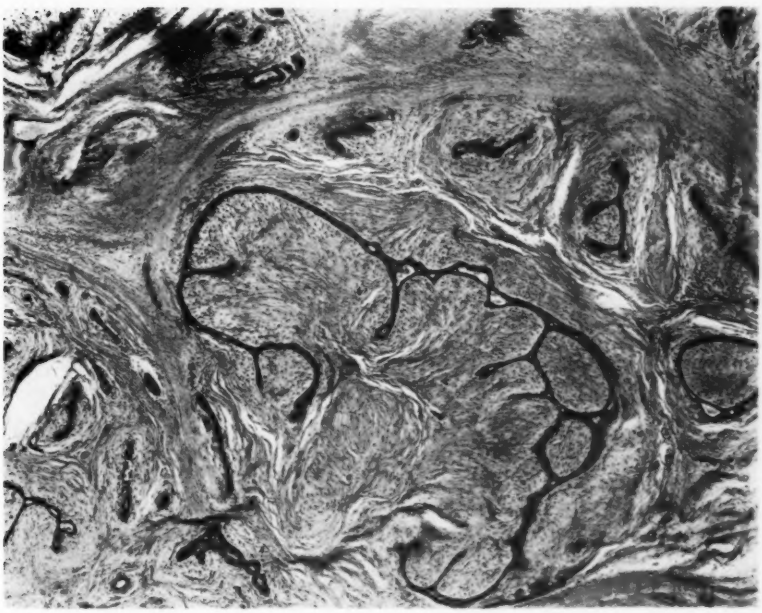
There were 27 cases which come under the classification of periductal fibroma in this series. These tumors correspond in gross and microscopic pathology and in clinical characteristics with tumors which have been reported by other writers by a variety of different names, such as "chronic mammary tumor," "cystosarcoma," "intracanalicular papillary fibroma," "fibroma," "adenofibroma," "fibro-adenoma," "intracanalicular myxoma," "adenocele," etc., a sufficient indication of the confusion which has existed in the minds of different pathologists and surgeons with regard to the assignment of these tumors to their proper category.

The pathological characteristics of the 27 periductal fibromata were as follows: 20 were single tumors; 7 were multiple. The size of the tumor varied in this series from that of a small marble to a mass as large as an orange. The tumors affected the right and left breasts with equal frequency, and in two

FIG. 1.

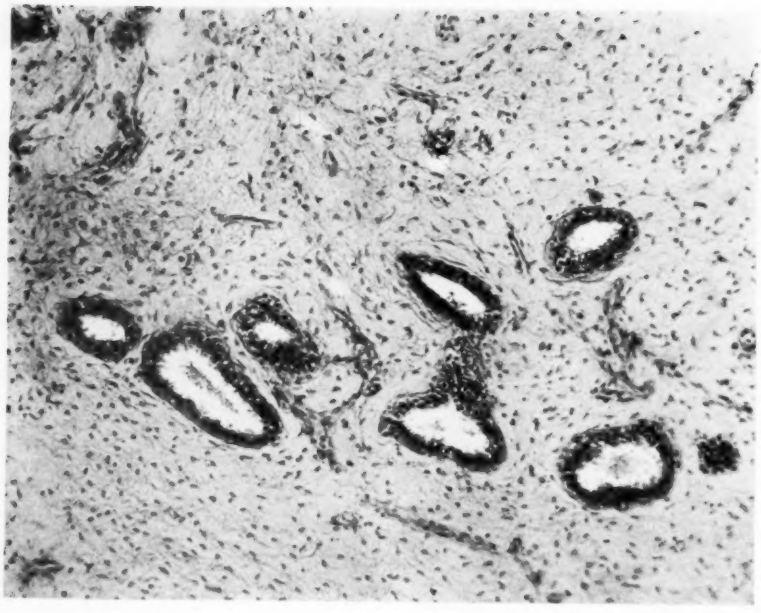
Periductal fibroma. Dissected tumor showing encapsulation and lobulation. Note small accessory nodule attached to larger tumor by slender stalk. (Warren Museum, Harvard Medical School.)

FIG. 2.



Periductal fibroma. Intracanalicular type. Low power, showing slit cysts, loose periductal fibrous tissue, and dense interlobular connective tissue.

FIG. 3.



Periductal fibroma. High power, showing loose periductal fibrous tissue and ducts. Resemblance to myxomatous connective tissue due to œdema.

cases there were tumors on both sides. Sixteen of the 27 were in the outer hemisphere against 8 in the inner hemisphere, and 13 in the upper against 8 in the lower half of the breast; 2 occupied a central position beneath the nipple and areola.

In contour the periductal fibroma is generally irregularly rounded and lobular. Small tumors by their rounded form and elastic consistency may closely resemble a cyst imbedded in the breast tissue. The consistency of the larger tumors, however, is distinctly hard and fibrous, although occasionally degenerative changes or cyst formation may produce perceptible softening of the tumor mass.

From the rest of the breast tissue the tumors of the periductal type are clearly separated by a distinct capsule. This is one of their most distinguishing characteristics. Some tumors in their earlier stages of growth possess a remarkable mobility, and can be slipped about from one place in the breast to another, by reason of the absence of infiltration in the surrounding tissues external to the capsule. Only in the rarest instances and in the case of the largest tumors, is there any indication of adherence to the skin or to the underlying structures, and then as a result of an inflammatory process such as may be produced by irritant applications or by the various forms of degeneration.

On section these tumors present an irregular surface, gray-white to pink in color, with either clefts or pearly translucent areas scattered here and there. Strands of dense connective tissue dividing the whole tumor into lobular masses are frequently observed. In many tumors an œdematous condition of the fibrous tissue, both gross and microscopic, occurs, which produces a gelatinous appearance and has led to their classification as myxomata by certain writers. The pearly translucent spots on the cut surface are the divided ducts and lobules of the tumor, and clefts and small cysts are not infrequently produced by the distortion or blocking of these ducts. In large tumors the cleft formation may be so pronounced as to give the appearance of a large cyst nearly filled with many rounded papillary outgrowths of fibrous tissue projecting from its walls (intracanalicular papillary fibroma).

On miscroscopic examination these tumors are composed of a stroma of fibrous tissue, through which pass epithelial-lined gland ducts, cysts or clefts. The fibrous tissue is itself divided into lobular masses by bands of dense connective tissue which form the framework of the whole tumor and support the blood-vessels and lymphatics. The whole mass is thus to be compared to a distorted replica of one of the racemose gland lobules of the mammary gland. The fibrous tissue which forms the bulk of the tumor is similar to that which immediately surrounds the ducts in the adolescent breast to which attention was first called by Billroth, and more recently by Warren. This tissue is delicate and rich in nuclei as compared to ordinary connective tissue and its cells have more oval and vesicular nuclei. It also appears to be more succulent, and its fibres are often separated by collections of fluid, which give it an œdematous appearance and produce marked variations in the color reaction in specimens stained with hæmatoxylin and eosin.

The epithelial elements of the tumor appear on microscopic examination as epithelial-lined ducts, or cysts, or clefts. Their number and character vary in different tumors and frequently in different portions of one tumor. They undoubtedly arise from the ducts of the mammary gland, or from the embryonic epithelial elements from which the ducts are derived, but they do not appear to be continuous with the ducts which open at the nipple. In many cases the epithelial elements are few in number, and present the appearance of gland ducts of varying size, which have been distended and distorted by the growth into and around them of the periductal fibrous tissue. This produces the slit cysts so characteristic of these tumors, which have led to their being called " intracanalicular papillary fibroma." In other instances the epithelial elements are more numerous and appear to have kept pace with the growth of the fibrous tissue, so that in place of the distorted clefts a uniform tissue is produced, consisting of many small epithelial-lined tubules separated by a stroma of periductal fibrous tissue. In some cases a grape-like grouping of the smaller lobules can be

recognized. In others the orderly arrangement is lost, and the lobules lie helter-skelter in the fibrous stroma. The tumors of this latter variety have usually been classified as fibro-adenoma or adenofibroma, and Rodman has recently adopted the term "pericanalicular" to describe them, as opposed to the tumors with the slit cysts or clefts which he calls "intracanalicular." It seems to us best to retain them both under one heading, because, although the two extremes of type can be clearly recognized, there are many tumors which show the characteristics of both classes, and a distinction in every case is an impossibility. It is certain, however, that the "intracanalicular" type is the more common.

The epithelial cells of these different forms of gland ducts are of much variety. In the larger clefts and ducts compressed columnar cells, similar to those lining the larger milk ducts, are usually found. In the smaller lobules, cuboidal, more clearly defined, and larger cells are present. When cysts are formed all varieties of epithelium, from flattened to cuboidal and even high columnar cells, are sometimes present. From the characteristics of the epithelium we have at times supposed that in the tumors of the "intracanalicular" type the process originated in the larger ducts, whereas in the "pericanalicular" group it was the terminal portions of the gland ducts (acini) which were concerned. This supposition, however, is quite incapable of proof. Cysts occur in tumors of both groups, but in the pure pericanalicular tumors they are rarely of large size while in the other class they may obtain considerable dimensions.

The activity of growth of the ductal epithelium in these tumors seems to be of slight extent. Occasionally a mitotic figure is observed, but the impression is given that the epithelium has merely kept pace with the changes of size and shape of its basement membranes, produced by the new growth of the periductal tissue. It is true that a certain number of tumors, which probably originate in the periductal group, do show greater epithelial activity than has been described above, but these tumors will be discussed further on, under a separate class as "fibrocystadenomata."

The clinical characteristics of the periductal fibromata are fairly well defined. They are the common tumors of the breast in young women. In a table prepared for a paper by Dr. Warren it was found that they gave 45 per cent. and 50 per cent. of the tumors in the breasts of women from 10-20 and 20-30 years of age, while in later decades the proportion diminished very rapidly. Of the 27 cases in this series the oldest was 40, the youngest 15, and the average 28.8. The majority occur in unmarried women, and the tumor is independent in its origin of the stimulus of pregnancy or lactation. They are, as a rule, of slow growth and of long duration, the average in our series of cases being 22.1 months before operation. In some cases a sudden period of rapid growth may supervene after a long time of relative quiescence. In other cases an increase in size of the tumor has been distinctly noted during the menstrual period, and this is often accompanied by an increased sensitiveness, if not by actual pain. In only 9 of the 27 cases, however, was pain of any kind complained of, and then it was usually described as of but slight significance. In some patients, however, a tumor of this nature may be the cause of considerable suffering, not only from the sensitiveness of the tumor but also from the mental anxiety with accompanies it.

Discharge from the nipple is not produced by periductal tumors. In only one case of this series was a discharge of any sort discovered, and in that case, a woman who had borne two children, the discharge was milk.

The attempt was made to distinguish between the intracanalicular and pericanalicular types of periductal tumors in regard to their clinical symptoms, but without success. There were four tumors that fell in the pericanalicular group, and three showed the characteristics of both classes, while in the 20 others no marked involvement of the smaller terminal branches could be made out. The clinical appearance of the tumors of the pericanalicular type were not distinguishable from those of the other classes, and the distinction is not, we believe, one of any great significance, although the difference

in the histological picture of the two tumors is considerable.

The diagnosis of the periductal fibroma depends upon the following characteristics: It appears in young women, is of slow and almost painless growth. Multiple tumors are not uncommon. It is freely mobile in the breast tissue, has well-defined margins of rounded and lobular outline, and has a consistency which is hard, but often elastic. It is almost never adherent to the skin or to the chest wall, and of course does not cause enlargement of the axillary glands. No discharge from the nipple is produced.

The periductal myxomata and sarcomata are usually larger tumors, and readily undergo degenerative changes causing areas of softening. The skin over them is generally thinned and often stretched so tightly as to appear to be adherent.

The papillary cystadenomata are small tumors, centrally situated, cystic, and may frequently be recognized by the discharge of blood from the nipple. When this symptom is absent (as in about 50 per cent. of cases) the diagnosis from a periductal tumor may be difficult. The cystadenoma, however, occurs more frequently in older women.

The fibrocystadenomata do not differ materially in clinical signs or symptoms from the periductal tumors. In some cases the fibrocystic tumors are of long duration and of larger size, and the recognition of definite elastic or fluctuating cystic areas in the tumor may be suggestive, but, as a rule, the fibrocystadenomata are operated upon as periductal tumors, and recognized only on microscopic examination.

Chronic inflammatory processes in the breast, such as tuberculosis, syphilis, actinomycosis, chronic abscess, and diffuse galactophoritis after lactation, produce less well-defined tumors, are usually adherent to the surrounding tissues, and often show inflammatory changes, and even discharging sinuses. The axillary glands are also frequently involved to a greater or less extent.

Cystic disease of the breast occurs at about the time of the menopause, and produces an induration less well defined than the periductal tumors. Cysts deep in the gland, or sur-

rounded by dense fibrous tissue, may give to the examining fingers a sensation not unlike that of a small periductal tumor in a younger woman. The diffuse and often bilateral character of cystic disease and the greater sensitiveness it produces will usually serve for its recognition.

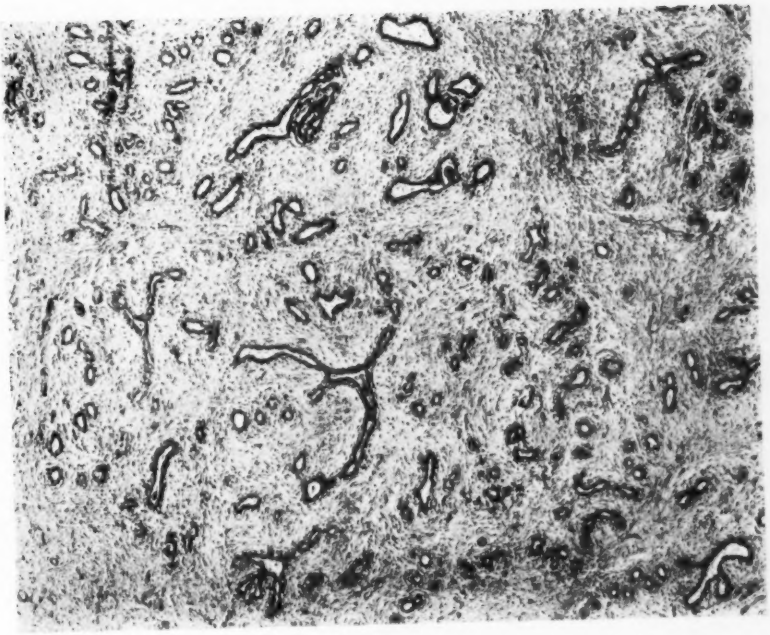
Carcinoma of the breast is distinguished from periductal fibroma by its characteristic symptoms of indefinite outline, early adherence and loss of mobility, and invasion of axillary nodes. Cancer is expected in older women, while the periductal tumor is usually one of earlier onset, although in one case of this series medullary cancer was present in one breast and a periductal tumor in the other at the same time.

Sarcoma of the non-indigenous variety, though a rare tumor in the breast, is more likely to be confused with carcinoma than with other diseases. Its early infiltration and adherence and its rapid growth make the diagnosis of malignancy most probable.

Finally the tumors which are not peculiar to the breast, such as lipoma, enchondroma, angioma, etc., are to be differentiated by their characteristic symptoms, and occur so rarely in this situation as to merit little consideration in differential diagnosis. It is to be remembered, however, that few surgeons are sufficiently expert or sufficiently ready to accept the grave responsibility of depending upon the differential diagnosis of any tumor of the breast, from clinical appearances alone, to advise against operation. No tumor of the breast is innocent or incapable of harm to the patient until it has been removed. The differential diagnosis is of great importance in determining the appropriate treatment, and many a breast could be saved if the establishing of a diagnosis were more carefully attempted—not with the idea of avoiding operation, but with the intention of securing the operative treatment best suited to the individual case.

Treatment.—The treatment of periductal fibroma, like that of all other tumors of the breast, is by removal. In some cases of multiple tumors of small size in both breasts, writers

FIG. 4.



Periductal fibroma. Pericanalicular type. Low power, showing gland ducts only slightly distorted, but separated in stroma of periductal fibrous tissue. Compare with Fig. 2.

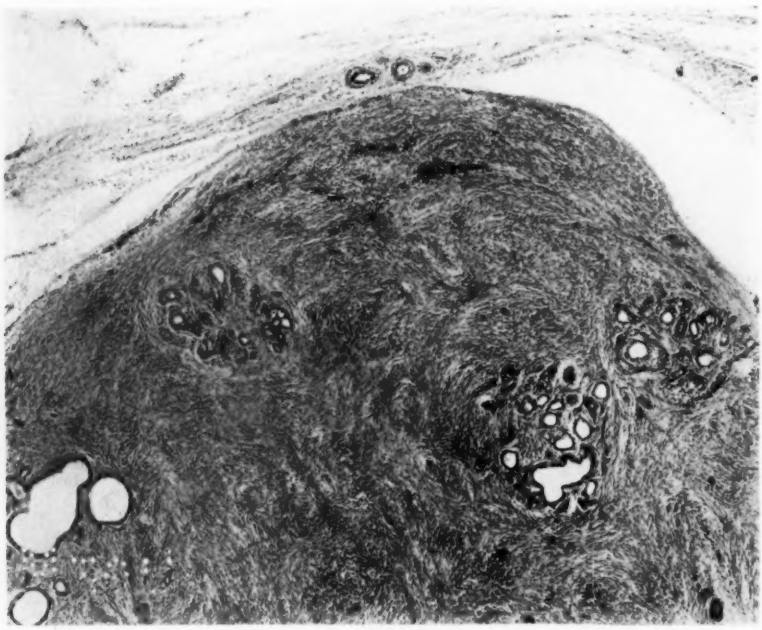
FIG. 5.

Periductal myxosarcoma. Clinical appearance.

FIG. 6.

Periductal myxosarcoma. Gross appearances of preceding tumor. Note encapsulation, volume of tumor, cysts, and rounded, papillary intracystic projections.

FIG. 7.



Periductal myxosarcoma. Low power. Portion of tumor showing cell-rich stroma of sarcomatous periductal tissue, gland ducts, and cysts and encapsulation.

FIG 8.

Periductal myxosarcoma. Low power. Portion of same microscopic section as Fig. 7; showing no evidence of sarcoma, but typical periductal fibroma; other portions of this tumor showed typical myxomatous tissue in the stroma.

have advised against operation (Bloodgood), but so extreme a case has not come to our attention. Of this series of 27 cases, in 14 the tumor or tumors were excised through an incision directly over the tumor. In 11 cases a "plastic resection" was performed after the method advocated by Dr. Warren, the tumor being removed from underneath through an incision along the axillary and inferior margins of the breast. In 2 cases amputation was done: once under a mistaken diagnosis, and once because of the large size of the tumor. It is probable that with the exception of the very small and superficial tumors, the "plastic resection" is the operation of choice, as it places the scar in an inconspicuous position and does not add materially to the difficulties of operation: even the largest tumors may be removed by this method, and when the displaced breast tissue is drawn together a fairly respectable looking mamma will result.

PERIDUCTAL MYXOMA AND SARCOMA.

We have been able to collect six cases which can be placed in the myxosarcoma group. If an arbitrary division were attempted, four of these cases would be classed as periductal sarcoma, and two as periductal myxoma. We believe, however, that such a division is unnecessary and undesirable, and that the tumors of this character are best described under the one term "periductal myxosarcoma." They have heretofore been described in medical writings under a variety of different terms —cystic or cystosarcoma, adenosarcoma, fibromyxosarcoma, fibrosarcoma, cystosarcoma phyllodes, etc. The relation they have to the periductal fibromata and their differentiation from the simple or non-indigenous sarcomata, which occur but rarely in the female breast, have not always been clearly drawn. In a series of 658 consecutive cases of breast tumor taken from the records of the Massachusetts General Hospital,[8] there were 459 cases of carcinoma (69 per cent.); 14 of myxosarcoma (2 per cent.); 48 of periductal fibromata (7 per cent.) and 4 of non-indigenous sarcoma (0.6 per cent.). The peri-

[8] Warren, J. C.: Jour. A. M. A., July 15, 1905.

ductal myxosarcoma, though a rare tumor, is the most common form of sarcoma of the breast.

The gross characteristics of the myxosarcoma in the six cases here collected were well defined. Single tumors were present in five cases, and a tumor was present in both the right and left breast in one case. The tumors were of relatively large size, the smallest being 5 cm. in diameter, and the others being estimated as of the size of an apple or orange up to that of a child's head. They practically occupied or displaced the whole breast, so that their situation in that organ could not be determined. The consistency of the tumors was usually described as hard, and the surface as irregularly lobulated; rarely cystic areas were recognizable, in one case a cyst the size of a grape-fruit being present.

Adherence of the skin over the tumor was noted in but two cases, and in one of these there was actual ulceration and an offensive discharge from the necrosing tumor tissue. In several cases, dilated veins over the tumor were recorded.

On section of the tumor, after removal, the usual description was that of a grayish, more or less translucent tissue, in lobular arrangement, with cyst or cleft formation. Complete or partial necrosis of the tissue was present in two cases. Cysts varied in size from microscopic dimensions to one the size of a grape-fruit, the contents being serous or brownish fluid. Papillary outgrowths into a cyst cavity were present in four of the six cases. In four of the six cases definite mention is made of a capsule delimiting the tumor from the breast tissue.

The microscopic sections of these tumors showed a characteristic though varied picture. The stroma of the tumor is composed of more or less cellular connective tissue, separated into lobules by strands of ordinary fibrous tissue. Through the stroma are scattered epithelial-lined ducts, cysts, or clefts. The connective tissue almost always varies in different portions of the specimen, and presents all gradations from the loose, fibrous tissue of the periductal fibroma, through the more cellular myxomatous tissue with stellate cells and delicate pro-

cesses, up to the richly cellular compact tissue of a fibrosarcoma. Tissues of these different cell characters not uncommonly lie side by side in the same preparation, and it is on this account that the differentiation of the periductal myxoma from the periductal sarcoma is so difficult and, we think, unnecessary. In the more cellular portions of the tumor mitotic figures may be seen. Necrosis and gelatinous or hyaline degeneration of the tissue were common in the larger tumors.

The epithelial structure consists of ducts, clefts, and cysts, lined with one or more layers of epithelium, exactly similar in every way to the epithelial elements of the periductal fibroma. In fact the resemblances of the two groups of tumors, not only from gross and microscopic appearances but from clinical symptoms as well, are such as to force upon the observer the conclusion that the myxosarcoma is a periductal fibroma, the fibrous tissue of which has more or less taken on the change in characteristics (anaplasia) which marks the advance from benign to malignant tumor growth—a change which, whether correctly or not, is often spoken of as "degeneration."

The clinical symptoms of periductal myxosarcoma are fairly well defined. They occur at a period later in life than the periductal fibroma, the youngest of our six cases being 36, the oldest 53, and the average 49 years. Three were in single and 3 in married women, and lactation appeared to be in no way associated with the onset or progress of the tumor. In one case a blow received upon the breast was thought to have occasioned the appearance of the tumor which had not before that time been detected.

The rate of growth of the tumors is comparatively rapid: one tumor in eight weeks grew to be the size of an orange; and another after incomplete removal grew in five weeks to the size of a child's head. In a third case, a small tumor was present for 12 years, but began to grow rapidly five weeks before entrance, and attained a size of 10 x 20 cm. at operation. No retrogression in size was ever noted, and no discharge of fluid from the nipple. In one case the nipple was thought to have been retracted. No

pain was caused by these tumors, although the weight of the breast and, in one case, the ulceration caused discomfort. The axillary glands were not noted as enlarged except in one case, where a small, soft gland was felt and removed at operation but no evidence of sarcomatous involvement of it was recorded.

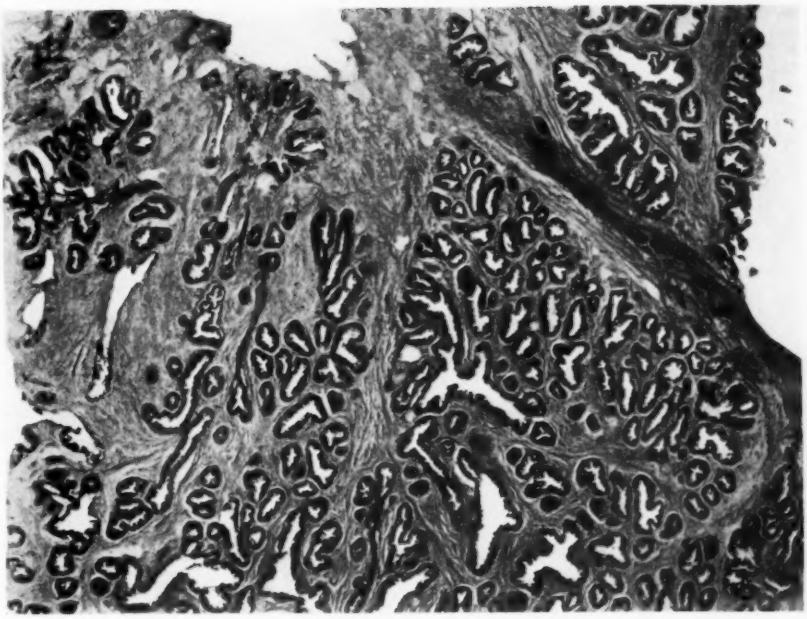
The diagnosis of periductal myxosarcoma should not be difficult. The tumors occur later in life, as a rule, than the fibroma, and are of larger size and more rapid growth. They are encapsulated and non-adherent unless necrosis of the tissue occurs or the skin is stretched and thinned over the tumor so as to favor ulceration. No carcinoma of the breast reaches such a size without its diagnosis being certain from the involvement of the skin and muscles and of the axillary glands.

The treatment should be complete removal of the tumor by amputation of the breast. The axillary contents and the pectoral muscles, however, do not need to be removed. Of the six cases here reported five had amputation of the breast, and in one case an excision was done. The excision is free from recurrence 7½ years after operation. Of the five amputations 2 are dead, one of unknown cause nearly 2 years after operation, one of pneumonia 4 years after operation, when about to undergo operation for a tumor in the other breast, which was thought by her attendant to be a recurrence of the sarcoma although no local recurrence in the scar of the first operation had taken place. Two of the other amputations were well 8 years and 1 year respectively after operation, and of one case no data could be obtained. One of the cases in which amputation was successfully performed had had a tumor the size of a hen's egg (a myxofibroma) excised 3 years before. Thus excision of the tumor without amputation must be considered hazardous, but a complete amputation should be expected to result in permanent relief.

FIBROCYSTADENOMA.

The tumors of this group are what might be termed the epithelial type of the periductal fibromata, and differ from them

FIG. 9.



Fibrocystadenoma. Low power, showing large number of gland ducts and cysts in proportion to stroma, and active proliferation of epithelium.

FIG. 10.

Fibrocystadenoma. Low power, showing proliferation of epithelium on papillary projections into a cyst.

only in the relation of the component parts. In the periductal fibromata the epithelial structures of the glands and ducts appear to be passively distorted by the growth of the periductal tissue. The fibrocystadenomata, on the other hand, although showing a growth of periductal tissue, have as their main characteristic a marked hyperplasia of the epithelial elements. A hard and fast line between the two tumors cannot always be drawn, because the diagnosis depends on the impression of the relative activity of the growth of the two component tissues. In fact, it is doubtful whether any special importance would attach to the making of this distinction if it were not for the fact that, because of the predisposition of the breast to cancer, active proliferation of the adult gland epithelium from any other cause than pregnancy and lactation is to be regarded with suspicion.

In the fibrocystadenoma group of the fibroepithelial tumors there were ten cases, in two of which both breasts were affected. In the hospital records these cases had been variously classified and many different pathological names had been applied to them, but in comparing them they all seemed to belong in the same group. Five were diagnosed as fibrocystadenoma. To one the term adenoma had been applied, two were diagnosed as periductal fibroma, one as adenofibroma, and one as intracanalicular papillary myxofibroma.

In gross, the tumors all appeared firm, elastic, well-encapsulated growths, varying in size from 2 cm. to 7 cm. in diameter. They were for the most part roughly round in shape, but the two largest, both over 6 cm. in diameter, were lobulated. In consistency they were described clinically as " hard " six times and twice as " firm," while in the pathological reports they were variously designated as firm, elastic, or fibrous.

On section the tumors had the general appearance of the periductal fibromata. The tissue was firm, fibrous, and usually of a dull white color, although in some cases it was somewhat translucent—this probably being due for the most part to œdema. On the cut surface numerous soft, glistening points

representing the ducts and acini could be seen, these being relatively more numerous than in the periductal fibromata. In but one case did the growth in gross show marked slits, then it was intracanalicular in type. In the three largest tumors there were many small cysts, these varying in size up to 1.5 cm. in diameter. In two of these the cysts were filled with clear, straw-colored fluid, while in the third the contents were described as pultaceous.

The chief and characteristic difference of these tumors from the periductal fibromata is the proportionately large amount of epithelium in relation to the fibrous tissue. The epithelium is the tissue which appears to show the most active growth. The tumors have a distinct, dense, fibrous capsule. Within this there is a tendency to a lobular arrangement of the tumor tissue, which is less marked or may be absent in the smaller growths. The stroma is as that of the periductal fibroma—loose, cellular, fibrous tissue without round-cell infiltration, evidently derived from the connective tissue immediately around the ducts. Two chief types of the growth may be distinguished as in the periductal group, *i.e.*, the pericanalicular and the intracanalicular types; of these the former is the more common, and although the two types merge somewhat, one into the other, the suggestion is strong that the periductal fibromata of the pericanalicular type are those from which the fibrocystadenoma is chiefly derived. Cysts lined with one or more layers of epithelium are present more frequently than in the fibroma group, and the ducts themselves have a great variety in appearance. In some cases the glands and ducts seem comparatively normal, but are increased in numbers beyond the conditions found in the normal non-lactating breast tissue. In other cases they are much distorted, while in still other instances the cells lining them show all the characteristic proliferative changes seen in cases of abnormal involution or cystic disease of the breast. Thus, while many glands are lined with a single layer of cuboidal or columnar epithelium, others show a heaping up of the cells forming papillary growths projecting into the lumen, and this process may be

so pronounced that the lumen is entirely plugged. The cells may even have an adenomatous arrangement, which is what might be termed the most extreme type of epithelial proliferation, and is similar to that seen in the abnormal involution cases which have a tendency to progress to carcinoma.

The patients varied in age from 15 to 44, the average of the ten being 30.5 years. Five were married and five single, but the records were too imperfect to allow any conclusions to be drawn as to the relation of lactation to the tumors. The length of time elapsing between the discovery of the growth and the seeking of medical advice varied from three months to five years, but the duration bore no relation to the size of the tumor. Thus one tumor of the size of an orange was of only three months' duration, while a tumor the size of a pigeon's egg had been present five years. No mention was made of the tumors varying in size, with the exception of one case in which fluctuation in size was quite marked, but had no relation to menstruation. In this case the change in size was probably dependent on the filling and emptying of cysts which were present in large numbers. In no case was a discharge from the nipple noted.

Five patients complained of pain, and in three cases the pain was neuralgic in character, shooting down the arm (mastodynia). In the other two it was spoken of as "slight." It had no relation to the catamenia. The right breast was the seat of the tumor five times, the left three, while in two cases both breasts were involved. In only one of these two, however, were both breasts operated upon, and in this case, while one of the tumors was a typical fibrocystadenoma, the other could best be classified in the periductal group. The tumors occupied any position in the breast, and varied in size up to that of an orange. They were freely movable over the deeper parts, and not adherent to the skin even when of large size. In but two cases was the presence of enlarged axillary glands noted.

It is practically impossible to differentiate between the periductal fibromata and the fibrocystadenomata clinically. The

average age of the patient, the rapidity of the growth, and the portion of the breast involved are the same. Neither is adherent, nor are enlarged glands usually present in the axilla. In a few of the larger tumors it may be possible to palpate the cysts if any are present, and thus establish the diagnosis, but true fluctuation in small breast cysts is extremely difficult to determine. For the differentiation of the fibrocystadenomata from the tumors of the breast other than the periductal fibroma, the reader is referred to the differential diagnosis of the fibromata given above. The treatment also is that of the periductal fibroma, that is, excision of the tumor, performed when possible by the "plastic resection" method. The prognosis is, of course, favorable, and no recurrence will take place after thorough removal.

SUMMARY.

A comparative study of the fibro-epithelial tumors of the breast shows that their relations one to another are very close, and justifies their being grouped together as in the Warren classification. The essential feature of the tumors of the fibrous type is the presence of periductal fibrous tissue in more or less abundance about the gland ducts. This periductal tissue may vary in cell richness from normal fibrous tissue to myxomatous or sarcomatous tissue. The two types of tumor, however, with this exception are so much alike that the sarcoma type may be well considered merely a modification of the benign fibroma. The periductal fibroma needs only excision of the tumor to effect a cure. For the periductal myxosarcoma, amputation of the breast is advised, without removal of the muscles or dissection of the axilla; the tumor is only locally malignant.

The fibrocystadenoma group includes a few tumors of similar origin to the foregoing, which display, when examined by the microscope, a tendency to epithelial overgrowth. The diagnosis between fibrocystadenoma and periductal fibroma cannot be made with certainty before the removal of the tumor. This tendency to epithelial proliferation is encoun-

tered in other diseases of the breast, such as abnormal involution of cystic disease; and is an undoubted source of danger to the patient in adult life. For this reason, complete removal of any fibro-epithelial tumor of the breast by early operation is the best treatment to be advised.

ABSTRACT OF CASES.

Periductal Fibroma.

Case G. (562-241.) Dr. C. L. Scudder.—21, single. History deficient. Small fibrous tumor of breast removed at operation for appendicitis. *Mx.* irregularly dilated ducts, flattened epithelium, slit cysts. Periductal fibroma.

Case H. (CXLII., 49.) Dr. F. G. Balch.—25, single. 7 years' duration. Pain, especially at cta. Size marble, lower outer quadrant right breast. Non-adherent, excised. Two small nodules, myxomatous (œdematous) fibrous tissue with cavities. Intracanalicular type. Periductal fibroma.

Case F. (526-221.) Dr. R. B. Greenough.—23, married, children, long duration, no pain. Entrance diagnosis, fibroma. Two tumors outer hemisphere left breast, size of orange and chestnut. Hard, not tender, non-adherent. Plastic resection. Two lobulated nodules, few cysts, pericanalicular type. Some epithelial proliferation. Periductal fibroma.

Case D. (516-21.) Dr. R. B. Greenough.—31, widow. 4 weeks' duration, no pain. Patient had left breast amputated for carcinoma 6 months previous. Nodule size of chestnut, outer hemisphere right breast. Hard, non-adherent, not tender. Excised. Tumor 8 x 3 cm., encapsulated, myxomatous with clefts. Intracanalicular type. Clefts lined with single layer epithelium. Œdematous fibrous tissue. Periductal fibroma.

Case 161. (XLVII-124.) Dr. W. M. Conant.—26, single, six months', no pain. Tumor size of large bean, right breast, upper inner quadrant, not tender, non-adherent. Similar tumor removed from right breast three years before. Excision. Fibrous tumor, white, hard. Mx. shows few ducts and cysts. Intracanalicular type. Papillary fibroma.

Case 42. (398-138.) Dr. J. C. Warren.—35, single, six months, slow growth, no pain, left breast, size of walnut, upper outer quadrant, not tender or adherent. Excised. Encapsulated tumor, gray, with slit cysts. Intracanalicular type, œdematous fibrous tissue. Periductal fibroma.

Case 113. (449-55.) Dr. S. J. Mixter.—27, single, 10 years, slow growth, tumors both breasts, size of small egg and smaller, hard, non-adherent. Excised. Tumors firm, white, with slit cysts. Intracanalicular type. Periductal fibroma.

Case 185. (LXXXIII-211.) Dr. H. H. A. Beach.—19, single, 1 year, slow, fluctuation in size, slight pain. Tumor size of hen's egg, right breast, hard, non-adherent, not tender. Excised. Encapsulated lobulated tumor, fibrous, with slit cysts. Intracanalicular type. Slight epithelial activity. Periductal fibroma.

Case P. (537-379.) Dr. J. G. Mumford.—38, married, three children,

eight months, slow growth, slight pain. Tumor size orange, centre, right breast. Slightly tender, non-adherent. Amputation. Encapsulated tumor, translucent, gray, slit cysts, œdematous fibrous tissue, few small cysts. Periductal fibroma.

Case 200. (480-107.) Dr. C. L. Scudder.—37, married, two children, five months, no pain. Tumor size of orange, centre right breast, hard, nipple exudes milk, both sides, non-adherent. Amputation. Encapsulated tumor, firm, translucent, gray, slit cysts. Intracanalicular type. Periductal fibroma.

Case 180. (LXXV-243.) Dr. A. T. Cabot.—36, single, ten months, no pain, tumor size of horse chestnut. Lower hemisphere left breast. Hard, non-adherent. Excised. Encapsulated tumor, fibrous, with slit cysts. Intracanalicular type. Periductal fibroma.

Case 112. (423-93.) Dr. H. H. A. Beach.—27, single, 1½ years, slow growth, no pain. Right breast, inner hemisphere. Tumor 2 inches in diameter. Soft, non-adherent. Amputation. Fibrous tumor with irregularly dilated ducts and slit cysts. Intracanalicular type. Periductal fibroma.

Case 93. (375-186.) Dr. M. H. Richardson.—38, married, three months, slight pain, left breast, upper outer quadrant, size of walnut, hard, slightly tender, non-adherent. Excised. Several fibrous nodules in breast showing increase of fibrous tissue and proliferation of gland ducts. Pericanalicular type. Periductal fibroma.

Case 34. (388-54.) Dr. J. W. Elliot.—29, married, seven children, seven years' duration, slow growth, slight pain, two tumors size of walnut upper hemisphere right breast, hard, non-adherent. Resection. Three discrete fibrous tumors in substance of gland. Intracanalicular and pericanalicular in different areas. No epithelial proliferation. Periductal fibroma.

Case 196. (CIII-99.) Dr. W. M. Conant.—52, married, two children, one year's duration. Slow growth, no pain. Tumor 3 x 5 cm. upper outer quadrant left breast, hard, non-adherent. Partial excision. Tumor encapsulated, marked papillary construction. Intracanalicular type, slit cysts. Periductal fibroma.

Case 214. (LXIX-153.) Dr. C. B. Porter.—17, single, six months, slow growth, no pain. Tumor size of walnut, lower outer quadrant right breast. Hard, non-adherent. Excised. 2 cm. Tumor white, fibrous, slit cysts. Intracanalicular type. Periductal fibroma.

Case 212. (140-504.) Dr. J. C. Warren.—40, married, four children, 1 year, pain. Tumor size of pigeon's egg, right breast, upper outer quadrant. Hard, tender, non-adherent. Excision. Two tumors, encapsulated, gray, firm, slit cysts. Intracanalicular type. Periductal fibroma.

Case 208. (492-151.) Dr. J. C. Warren.—35, single, one year, slow growth, no pain. Tumor size of walnut, inner hemisphere right breast. Not tender or adherent. Excision. Encapsulated nodule, slit cysts. Intracanalicular type. Periductal fibroma.

Case 210. (492-269.) Dr. J. C. Warren.—32, single, three months' duration, no pain. Tumor size of hen's egg, upper inner quadrant right breast. Not tender or adherent. Excision. Firm fibrous tumor, slit

cysts. Intracanalicular type. Slight activity of epithelium. Periductal fibroma.

Case E. (CXXI-27.) Dr. H. H. Beach.—27, single, two years, no pain, left breast, outer hemisphere. Tumor size of egg, hard, slightly adherent (?). Excised. Flat oval tumor, lobulated, fibrous consistency. Pericanalicular type. Myxomatous connective tissue, no cysts. Periductal fibroma.

Case I. (570-83.) Dr. L. Davis.—15, single, 1 year, pain slight, tumors in both breasts, hard, 1 and 2 inches in diameter, non-adherent. Excised. Fibrous tumors with slit cysts. Intracanalicular type. Periductal fibroma.

Case M. (530-213.) Dr. M. H. Richardson.—33, married, 1 child, 3–4 years, no pain. Tumor size of orange, upper inner quadrant left breast. Hard, non-adherent. Excision. Two encapsulated tumors, gray, fibrous, slit cysts. Intracanalicular type. Periductal fibroma.

Case T. O. P. D. (133–190.) Dr. L. Davis.—19, single, two months, tumor size of walnut, upper inner quadrant left breast, non-adherent. Excision. Fibrous encapsulated tumor, 2 x 3 cm., lobulated. Intracanalicular type.

Case B. O. P. D. Dr. C. C. Simmons.—26, single, 1 year's duration, no pain, size of hen's egg, lower outer quadrant right breast, hard, non-adherent. Excision. Encapsulated tumor, fibrous, lobulated. Intracanalicular type, few cysts. Periductal fibroma.

Case Q. (596-133.) Dr. F. B. Harrington.—27, married, 1 year's duration, slow, slight pain. Tumor size of walnut, lower outer quadrant left breast, hard, non-adherent. Excision. Tumor encapsulated, 2 cm., nodular, myxomatous connecting tissue. Pericanalicular type. Periductal fibroma.

Case R. (CLVIII-129.) Dr. J. G. Mumford.—25, single, two years' duration, no pain. Tumor 1 inch in diameter, inner hemisphere left breast. Hard, lobulated, non-adherent. Excision. Encapsulated, lobulated growth, white, firm. Intracanalicular type, few small cysts. Periductal fibroma.

Case C. (503-251.) June, 1905. Dr. H. Williams.—17, single, eight weeks, some diffuse pain. Tumor size 3 inches, left breast, outer hemisphere, nodular, non-adherent. Excision. Encapsulated tumor, gray, white, slit cysts. Very cellular fibrous tissue. Intracanalicular type.

Periductal Myxosarcoma.

Case K. (561-121.) Dr. S. J. Mixter.—52, single, seven months' duration, following a blow, no pain. Tumor size of apple in central portion of left breast, hard, skin slightly adherent, veins dilated, no axillary glands. Amputation. Encapsulated, semi-necrotic, grayish tumor. Mx. shows spaces surrounded by cellular myxomatous tissue, epithelium of ducts degenerated. Periductal myxo-sarcoma. No recurrence one year later.

Case 94. (381-208.) Dr. S. J. Mixter.—49, married, three months' duration, no pain. Tumor size of walnut lower outer quadrant right breast, non-adherent, no glands. Excision. Lobular tumor, gray, translucent.

Minute cysts. Mx. shows cellular stroma with scattered epithelial tubules. Adeno-sarcoma. No recurrence eight years later.

Case 172. (LXVII.) Oct. 28, 1902. Dr. C. B. Porter.—53, single, twelve years' duration, rapid growth, 5 mos., no pain. Tumor size child's head, occupying left breast, non-adherent, no glands. Amputation. Encapsulated tumor, gray, gelatinous, with clefts. Mx. shows cellular myxomatous and sarcomatous tissue interspersed with gland ducts. Intracanalicular type. Periductal sarcoma. No recurrence one year later, died three years later of pneumonia. ? of tumor in other breast.

Case 178. (LXXIII-65.) Dr. A. T. Cabot.—51, married, 4 years' duration, slow growth, slight discomfort. Tumor 23 cm. in diameter, occupying left breast, ulcerated and skin adherent, dilated veins, no axillary glands. Amputation. Large tumor, gelatinous, lobulated, slit cysts. One large size cyst size of egg with papillary outgrowths, cellular fibrous and myxomatous tissue. Periductal myxoma-sarcoma. Patient died two years later, cause unknown.

Case 216 (XXXIII-45.) Dr. J. W. Elliot.—40, married, 1 child, tumor 8 weeks' duration, rapid growth. Tumor size orange, middle right breast, hard, non-adherent, one small axillary gland. Amputation with dissection of axilla. Encapsulated tumor 5 cm. in diameter, lobular, grayish, translucent. Mx., myxomatous tissue and gland ducts with some proliferation of epithelium. Periductal myxo-sarcoma.

Case 159. (XLVII-74.) Dr. W. M. Conant.—36, single, 4¼ years' duration. Tumor left breast, size hen's egg. 3½ years ago tumor in right breast size child's head. Operation three years ago. Amputation of right breast. Excision of left. Diagnosis: myxo-fibroma. Five weeks ago tumor developed in left breast, rapid growth, now size child's head, skin not adherent but discolored. Amputation. Encapsulated tumor with gelatinous tissue and cysts with brownish fluid and papillary projections. Periductal myxo-sarcoma. No recurrence 8 years later.

Fibrocystadenoma.

Case 50. (452-153.) Dr. C. L. Scudder.—38, married, 5 months' duration, slow growth, some pain. Tumor size of orange, inner lower quadrant right breast, hard. Excision. Encapsulated fibrous tumor, pearly-colored tissue, slit cysts. Mx. shows loose fibrous tissue, œdema (?), with active epithelial proliferation in cysts. Fibrocystadenoma.

Case 179. (LXXIII-187.) Dr. A. T. Cabot.—25, married, 4 years' duration, no pain, 4 tumors in right breast each about size of walnut, one tumor in centre left breast size lemon, non-adherent. Tumor on left excised. Fibrous tumor 4½ cm. with small cysts. Mx. shows much proliferation of epithelium. Fibrocystadenoma.

Case L. (523-85.) Dr. M. H. Richardson.—29, widow, 1 year, little pain, upper outer quadrant right breast, tumor size of orange, firm. Excision. Encapsulated tumor, œdematous, firm, with many cysts, loose fibrous tissue with active proliferation of glandular epithelium. Fibrocystadenoma.

Case N. (CXXVI-273.) Dr. F. G. Balch.—42, widow, 2 years' duration. Tumor size pigeon's egg upper outer quadrant right breast, non-adherent. Excised. Fibrous tumor 4 cm. in diameter, œdematous fibrous tissue, proliferation of epithelium in ducts. Small cysts. Pericanalicular type. Fibrocystadenoma.

Case 213. Dr. Torrey, June 28, 1902.—16, single, 8 months. Tumors in both breasts, one 2½ the other 3 cm. in diameter, hard, non-adherent. Excision. Both encapsulated tumors, white fibrous tissue and cysts. Active proliferation of epithelium, papillary projections. Fibrocystadenoma.

Case A. O. P. D. April 18, 1908. Dr. C. C. Simmons.—19, single, 5 years. Tumor size pigeon's egg upper hemisphere right breast, hard, non-adherent. Excision. Nodular, encapsulated tumor. Fibrous tissue, active proliferation of epithelium in cysts and ducts. Fibrocystadenoma.

Case S. (CLVII-129.) Dr. R. B. Greenough.—18, single, 1 year's duration. Slight pain. Tumor size egg lower hemisphere right breast, firm, non-adherent. Excision. Lobulated fibrous tumor. Active proliferation of duct epithelium and of periductal fibrous tissue. Pericanalicular type. Fibrocystadenoma.

Case O. (546-33.) Dr. C. L. Scudder.—44, single, 2 years' duration. Tumor size of horse chestnut, lower inner quadrant left breast, hard, non-adherent. Excision. Encapsulated tumor, hard, lobulated, gelatinous appearance. Myxœdematous fibrous type, with dilated and distorted ducts and active epithelial proliferation. Small cysts. Pericanalicular type. Fibrocystadenoma.

Case 104. (397-145.) Dr. M. H. Richardson.—36, single, 2 years' duration. No pain. Upper outer quadrant left breast. Tumor size of silver dollar, hard, non-adherent. Excision. Lobular tumor, circumscribed. Large epithelial ducts. Active proliferation.

Case X. Dr. H. Cabot, December 16, 1906.—38, married, 2 years' duration. Considerable pain. Tumor central in right breast, size of orange, hard, non-adherent. Excision. Lobulated tumor, encapsulated, circumscribed tissue. Small cysts. Ducts with epithelial proliferation. Fibrocystadenoma.

INTERCOSTAL DIAPHRAGMATIC HERNIA

WITH REPORT OF A CASE.

BY JOHN C. A. GERSTER, M.D.,
OF NEW YORK,
Assistant Surgeon to the City Hospital; Second Assistant Surgeon to the J. Hood Wright Memorial Hospital; Surgeon to the University and Bellevue Hospital Medical School Clinic.

THE occurrence of diaphragmatic hernia is not uncommon,[1] but even in the most recent literature on this subject little if any mention is made of its intercostal variety. The following case, therefore, seems to be of sufficient interest to justify its publication.

James McN., thirty-eight years old, single, a longshoreman, always enjoyed good health. He came to the Surgical Department of the University and Bellevue Hospital Medical School Clinic on December 13, 1910, for treatment of an infected abrasion of the right knee. By chance, a tumor of the left side of his thorax was observed. On being questioned about this, he stated that three years before, while working at a sawing table near a circular saw, he was hit on the left side of his chest by the end of a one-inch plank. He felt weak and was laid upon the floor, but did not lose consciousness. A doctor told him that he had a broken rib, but did not strap it. The patient stated that shortly after the accident he was "black and blue" on the left side, from the sternum to the vertebral column, and from the clavicle nearly to the pelvis. Treatment consisted in application of a salve and a bandage. After the ecchymosis began to fade, he noticed a painless tumor upon the left side, which never bothered him.

At no time had there been hæmoptysis, dyspnœa, vomiting, colic, or, in fact, any untoward symptoms. He had not noticed any progressive enlargement of the tumor since its first appearance.

Physical examination showed a large, well-built man, well nourished, in good general condition, in whom the findings were

[1] A. Salomoni (Clin. Chirurg., 1910, Nos. 5 and 6) mentions 1000 cases of diaphragmatic hernia, 50 of which were operated upon.

negative except for: (1) a superficial granulating wound of the right knee; (2) a painless, tensely distended bursa in front of the right ligamentum patellæ; and, (3) a painless swelling of the left chest wall, the size of half an apple, situated in the anterior axillary line, near the free border of the ribs (Fig. 1). This enlarged on coughing to a maximum size, 9 cm. long, 7 cm. wide, by 4 cm. thick (Fig. 2). The overlying skin was normal and freely movable. The tumor was entirely reducible through a gap in the thoracic wall between the eighth and ninth ribs, which measured 4 cm. long, 1 cm. wide, and could be closed by the tips of three fingers; its lower end was 4 cm. above the free border of the ribs (Fig. 3). No callus could be made out. Reduction occurred with greatest ease when the patient lay on his right side. The swelling then remained absent except upon straining or coughing. It reappeared a little upon each deep inspiration, and could also be made to appear by manual pressure upon the abdomen. The tumor appeared and remained present as soon as the patient took any position except that just mentioned (lying on right side).

At times reduction was accompanied by a gurgle. As just mentioned, the tips of three fingers closed the gap in the thoracic parietes; while two fingers could penetrate to a depth of 2 cm. (see X-ray plate, Fig. 5).

In the course of palpation the impression gained was, that omentum first came into the sac, forming its superficial contents, and behind it, especially upon maximum protrusion, came intestine. The percussion note over the hernia was identical with that obtained over the adjacent portion of the abdomen, quite distinct from the pulmonary resonance, which could be obtained just above its upper margin.

Auscultation revealed occasional gurgling intestinal noises. There was absence of vesicular sounds. No sounds were heard over the hernia while the patient was drinking.

From these findings it was concluded that the gut in the hernia was either a part of the transverse colon close to the splenic flexure, or part of the jejunum. Inflation per rectum was not done for fear of thereby losing the patient's attendance at the clinic.

Attempts were made to ascertain the exact nature of the hernial contents by administration of bismuth meals and bismuth

enemata, but, owing to the unreliability of the patient, it was impossible to obtain exposures at suitable times. In spite of these unavoidable gaps in the X-ray examination, some of the plates are of interest. Fig. 4 shows the hernia protruded. The difference in density between hernia and lung is very apparent. Fig. 5 shows two fingers inserted as deeply as possible through the defect in the thoracic wall between the eighth and ninth ribs.

The plates were made in the Gibbs Memorial X-ray Laboratory of the University and Bellevue Hospital Medical School, by the director, Dr. L. T. Le Wald, for whose valuable co-operation in the study of this case, I wish to express my gratitude and appreciation.

The patient does not desire an operation, stating that the hernia has never bothered him and that he does not believe it has grown any larger since its first appearance.

In view of his careless habits, I have not advised the wearing of any type of belt or supporter, believing that with his mode of life such an appliance might readily lead to strangulation.

In searching the literature, I found an excellent résumé of the subject by Alquier,[2] who collected nine cases. An abstract of these follows.

I. Cloquet, *Nouveau Journal de Médecine,* December, 1819. A soldier, 35 years old, was run over by a piece of artillery at the battle of Lützen. The wheel passed over his lower thorax and upper abdomen. He was sick and miserable for seven years; finally, in 1815, came under the observation of Cloquet.

A tumor, the size of a nut at first, which had later enlarged to the size of an egg, lay in the space between the left eighth and ninth ribs at their junction with the costal cartilages. It was irreducible and painful. Any bodily activities resulted in an enlargement of the tumor, and these, or any attempts at reduction, caused nausea, vomiting, and intense colicky pains. The man led a miserable existence. What became of him was not recorded.

II. Cruveilhier in his *Anat. Path. Générale,* liv. xxi, Pt. iii, describes a "hernie intercostale traumatique abdominale" in a soldier 70 years old, who had received a blow from a wagon tongue upon the left side of the thorax some years previously. A swelling, the size of a fist,

[2] Paul Alquier: "La Hernie Intercostale Abdominale," Thèse de Paris, 1905–6.

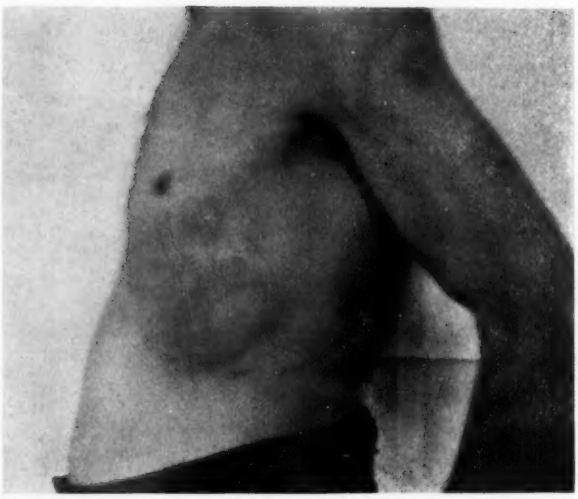
FIG. 1.

Shows the usual size of the hernia.

FIG. 2.

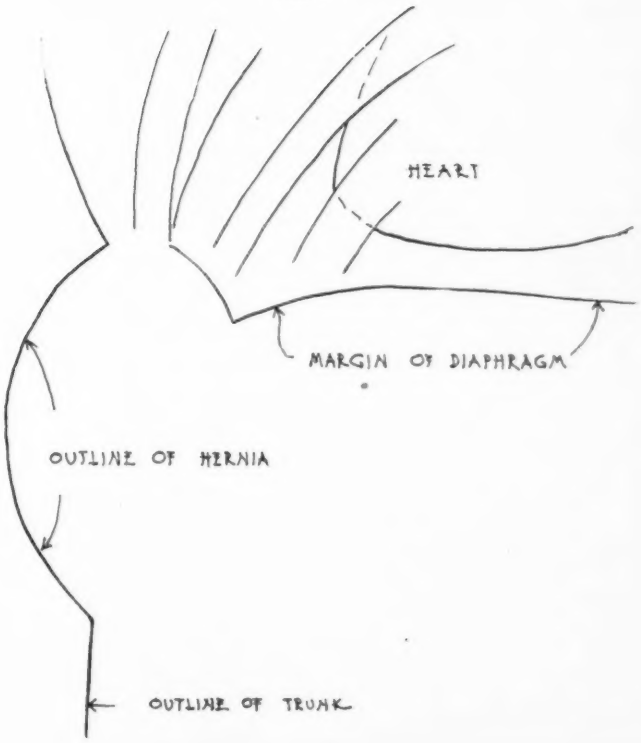
Shows the hernia at its maximal protrusion.

FIG. 3.



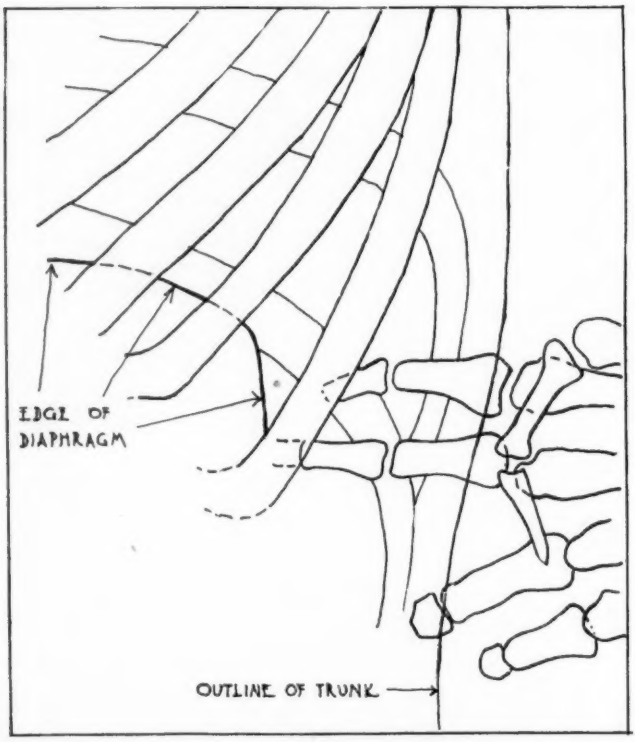
The free border of the ribs and the opening between the eighth and ninth ribs are indicated by pencil marks on the skin.

FIG. 4



Skiagraph of tumor site viewed transversely.

FIG. 5.



Skiagraph of tumor site viewed anteroposteriorly.

lobulated, with a sessile base, irreducible but varying in size, was noted at the site of injury upon the left thorax, close to the costal margin. The man died of cirrhosis of the liver in 1828.

At autopsy the lobulated tumor was shown to have a fibrous pedicle, located in the space between the left eighth and ninth ribs. The sac was found to contain omentum adherent to all its recesses, which were represented externally by the lobulations. The intercostal diaphragmatic opening easily admitted the index finger. Close to this opening were stomach and splenic flexure, evidently ready to enter.

III. Risel in the *Deutsche Zeitschrift f. Chir.*, Dec., 1875, Bd. vi, Hft. 3, p. 305, reports the case of a patient, 35 years old, who, in a fit of despondency seven months previously, had attempted suicide by repeatedly stabbing himself with a small blunt knife. The wounds healed, but later herniæ developed in the scars. One in the seventh left interspace, evidently contained omentum and gut, while one in the sixth interspace, was thought to contain stomach. An attack of bronchitis had caused rapid enlargement of the herniæ. No operation was done.

IV. Bazy's case was published by Iselin in *Gazette hebdomadaire de Med. et Chir.*, 1898.

A journalist, 26 years old, had been caught between two colliding wagons on Oct. 1, 1897. He sustained a contusion of the lower thorax and upper abdomen. An extensive ecchymosis immediately developed. Fifteen minutes after the accident a tumor appeared, which increased in size upon making the slightest effort. Hæmaturia lasted for some time, but finally ceased. He wore a belt on account of the tumor, but, because the apparatus became bothersome, he entered the hospital of St. Louis on March 12, 1898.

Examination showed a scar at the level of tenth rib. The tumor on coughing enlarged to the size of an ostrich egg. It was painless, tympanitic, and totally reducible. Upon reduction, the opening was found in the tenth space, extending from its anterior end, back to the mid-axillary line. By introducing the hand through this hole, the under surface of the diaphragm could be palpated.

The operation by Bazy was done on March 17, 1898. A 15 cm. incision was made corresponding to the long axis of the tumor. Beneath the skin lay a fibrous sac. On dissecting through this, the colon was accidentally opened. The opening was closed by suture. Careful dissection was then continued close to, and denuding the tenth and eleventh ribs until the peritoneal cavity was finally opened (the hernia evidently was then reduced), and the opening closed by a catgut suture. The tenth interspace was then obliterated by approximating the adjacent ribs by means of two catgut sutures passed through the ninth and eleventh spaces. Layer suture of the rest of the wound was made. An uneventful convalescence ensued. In place of the former hiatus, there was "un véritable plastron osseux." The patient was discharged cured, April 13, 1898.

V. Prat, in the *Archives de Médecine naval*, Oct., 1885, reported the case of a man who, five years previously, while lifting a wagon, had

felt a sudden sharp pain in the left side. He did not stop work. There was no hæmoptysis. Five days later a tumor the size of a pea appeared. This gradually increased in size and began to be inconvenient.

On June 25, 1885, the tumor had grown to the size of a hen's egg (6 cm. x 3 cm.). It was situated in the ninth left space, 5 cm. from the free border of the ribs. The tumor's volume increased on deep inspiration. The tumor was irreducible, but gave an impulse on coughing. It was tympanitic on percussion.

For the past three years the patient had suffered from irregular attacks of vomiting, accompanied by pain at the site of the tumor. There were also attacks of diarrhœa, not associated with the vomiting. Prat believed the case to be a hernia of the transverse colon and anterior margin of the stomach, causing a partial obstruction of the colon. No operation.

VI. DURAND, at a meeting of the *Société de Chirurgie de Lyon*, Aug. 7, 1904, presented a man, who was stabbed in the left side on April 27, 1903. The wound was located in the axillary line between the ninth and tenth ribs, admitted three fingers, and contained prolapsed omentum. There was no operation at that time. He made a smooth recovery.

One year later, April 27, 1904, he entered the hospital on account of a hernia in the scar. The mass was the size of a fist and gave an impulse on coughing. Reducibility and size of opening not mentioned.

X-ray (Destot) showed that the costophrenic space was obliterated at the level of the wound, and that the free pleural cavity was well above the proposed field of operation. At operation it was found that the hernia contained some omentum, which was resected. The transverse colon was pulled up into wound and again replaced. Layer suture of diaphragm, intercostal space, and skin. Recovery.

VII. DESTOT, at the same meeting, reported a case of Giverdey's, of a stout man in whom a hernia had appeared after coughing. It was located between the eighth and ninth ribs upon the left side. The size varied. Auscultation over the hernia revealed the presence of borborygmi, and, when the patient drank, splashing sounds. Inflation under the X-ray confirmed the diagnosis, that the hernia contained part of the stomach. The patient was made comfortable with an elastic belt.

VIII. SAVARIAUD, *Soc. de Chir.*, Dec., 1905.

In 1898 the patient, a truck driver of 41, was driving a vehicle which collided with an obstacle and rebounded violently.

He did not fall, but experienced a cracking sensation across the small of his back, followed by a sharp pain there. The man rested three months, but even then was unable to resume active work on account of pains in the back.

These pains occurred in crises of great severity, lasting from a few minutes to several hours. They were relieved by local blistering. The patient saw a number of physicians, who regarded his case as one of traumatic hysteria.

Savariaud found a reducible tumor the size of a mandarin orange in the tenth left space in the axillary line. It enlarged and gave an impulse

on coughing. On further questioning, the patient stated that the sharp prow of a boat had struck him there when a child, but he had never paid any attention to the site of injury.

Operation was performed Nov. 22, 1904. After incising the skin, the tumor was found composed of reddened fat distinct from the subcutaneous fat and covered with a cellular fibrous envelope. This fat proved to be omentum. The opening lay in the space between the tenth and eleventh ribs. There was a rudimentary sac around the orifice. The omentum was resected, revealing the spleen at the hernial orifice. A plastic closure of the orifice was effected by using part of the latissimus dorsi. Uneventful recovery.

IX. Scalzi (*Gazette medicale Italo Lombarde,* 1881) reported the case of a man who in 1870 had received 15 stab wounds. One of these, directed from above downward, had divided both eighth and ninth left ribs and perforated the abdomen; it was 5 cm. long. Through this wound a loop of intestine protruded, which was inflamed and distended to the size of an adult fist. The wound was enlarged 2 cm. and reduction of intestinal loop, first into the thorax and then into the abdomen through the diaphragm, was accomplished. The diaphragmatic and intercostal wounds were sutured, an appropriate bandage to lessen thoracic movements was applied, and the patient was kept lying on the left side. He recovered. There was no general reaction, and only a slight local pleurisy.

A hernia gradually developed in the scar. The hernia measured 10 cm. wide by 10 cm. long by 4 cm. high. It was tympanitic, painless, and entirely reducible. There were no symptoms referable to the digestive or respiratory tracts. The man was enjoying excellent health. He drank and ate heartily, and weighed about 250 kilogrammes! (?)

Besides the foregoing cases of Alquier, I have found four more, which are abstracted below.

X. "Medical and Surgical History of War of the Rebellion," Surgical Volume, Part I, p. 515.

Captain R. S., Co. A, 29th N. Y. Volunteers, received a gunshot wound at the battle of Chancellorsville on May 2, 1863. The ball entered the eighth left space, fracturing the ninth rib. The wound was 9½ inches to the left of the ensiform process. There was a hernia of the lung.

Five days afterward (May 7) the ball was voided at stool.

The patient made a good recovery and carried his pneumocele without discomfort.

Sept. 19, 1865, he began to have an irritable stomach, vomiting easily, etc.

March 14, 1867, a sudden enlargement of the tumor occurred while the patient was undergoing exertion. The tumor was partly reducible and borborygmi were noted over it. A pad was worn with good effect, so that in 1872 the tumor was much smaller, firm, and solid.

ADDENDUM.—Through the kindness of Dr. W. H. Hartzell of Allentown, Pa., I was able to learn that Captain S. died on August 20, 1893. His widow states that he suffered very much in his later years owing to adhesions of the stomach to the hernia, which protruded between the eighth and ninth ribs on his left side. Cause of death and postmortem findings were not obtained.

XI. LLOBET, *Onze annes de pratique chirurgicale,* Paris, Balliere, 1898. Cit. after Neugebauer, *Arch f. klin. Chir.,* Bd. 73, p. 1014, 1904.

Soldier of 58, wno 15 years before had received a stab wound in 8th left interspace between mammillary and anterior axillary lines. A swelling the size of a hen's egg developed at this point.

At operation a thoracoplastic flap was fashioned. The omentum and colon, found in the pleural cavity, were reduced, and the diaphragm was closed by suture. Operative recovery, but patient died six months later from an infection originating in a rib caries.

XII. P. MARZETTI and S. VENANZI, *Il Policlinico, Roma,* 1906, xiii, p. 1554–1556.

A peasant of 70, when 21 years old, had received a stab wound in the ninth left interspace between the mammillary and anterior axillary lines. The wound, which was 2 cm. long, was sutured. The patient made a rapid recovery.

A hernia appeared which gradually increased to the size of an orange. It always was easily reducible.

February 21, 1905, patient came to operation with an ileus of two days' standing. Under cocaine anæsthesia the sac was opened and found to contain omentum and a gangrenous loop of gut. This was resected. The defects in diaphragm and chest wall were repaired. Recovery.

XIII. P. POSTEMPSKI in the *Bull. d. r. Acad. Med. di. Roma,* 1888–89, xv, p. 191, reported the case of a boy with an epiplocele of the left eleventh interspace following a wound there. An intercostal incision sufficed to give adequate exposure (it was not necessary to divide ribs); 10 cm. of omentum were resected, the omental stump was reduced into the peritoneal cavity. The wound of the diaphragm (2.5 cm. long) was sutured with fine silk. Layer sutures of the rest of the wound. No drainage. Recovery.

An interesting feature of this case was the occurrence of a left pneumothorax upon freeing the omentum. Except for a subcutaneous emphysema of the left thorax and left side of the neck, there were no untoward results from this.

Etiology.—A study of the cases collected shows that intercostal diaphragmatic hernia has followed wounds from sharp objects or severe contusions along the left free costal border, and has even come on after strains, such as lifting heavy weights or coughing. The ribs may or may not be fractured.

The hernia may make its appearance shortly after the trauma has occurred, or it may develop much later.

Site.—The region where these hernias have been observed to occur comprises the anterior parts of the sixth to the tenth left interspaces, inclusive. That is, from the median line to the left midaxillary line, just above the left costal margin. This is a strip which lies between the lower margin of the lung and the free border of the ribs. The trauma causing a hernia in this region usually causes adhesion of the phrenic and parietal pleuræ also, with consequent obliteration of the costophrenic sinus. In this zone, close to the lower margin of the thorax, the diaphragm and intercostal muscles lie close to each other in almost the same plane; hence, rupture of tissue at this point (in the costophrenic space and sinus) favors formation of an intercostal hernia. Higher up, wounds involving both intercostal spaces and diaphragm favor the establishment of pneumothorax and of a diaphragmatic hernia which does not tend to emerge between the ribs.

The presence of the liver on the right side usually prevents the formation of herniæ in a corresponding situation there.[3]

Anatomy.—The opening may barely admit the tip of a finger, or may be large enough to permit the introduction of the entire hand. It usually is bounded above and below by the sharp edges of adjacent ribs, and in front and behind by the cicatricial margins of the remaining intercostal muscles in that space. The size of the hernia may vary from that of a pea to that of an ostrich egg.

A rudimentary attempt at sac formation is usually found near the neck of the hernia. Like in other traumatic herniæ, the occurrence of a sac is uncommon, and adhesion of contents is the usual condition.

The contents may comprise omentum, transverse colon or splenic flexure, stomach, or small intestine. These will again be referred to in discussing diagnosis.

Symptomatology.—The subjective symptoms may be nil; or, again, there may be much suffering from pain and diges-

[3] A case which might possibly have been an intercostal diaphragmatic hernia of the right side is described on page 516 of the Medical and Surgical History of the Civil War, Surgical Volume, Part I.

tive troubles due to adhesions, as seen in the case reported by Cloquet, where the patient became so miserable that he was described as presenting a "cachexie herniaire." However, these troubles are common to adhesions of the stomach and the intestines from other causes, and are therefore of no further interest here.

The objective symptoms are those of other herniæ. There may or may not be a scar, depending on the etiology. Increase in size on inspiration, a differential point of value, may not be obtained except in certain positions. In most cases, reduction was easy; in a few it was impossible. Where gut is present and the hernia is reducible, reduction with a gurgle can be obtained at times. The consistence of the herniæ and likewise the findings on percussion depend upon their contents, whether omentum, gut, or stomach.

Over herniæ which contained part of the stomach, typical intermittent splashing sounds were heard when the patient drank. Peristaltic borborygmi could be obtained over a hernia containing gut.

The X-ray is of great service in the diagnosis, even without the aid of bismuth. Much accurate information regarding what parts of the digestive tube are present in the hernia can be obtained by making a series of Röntgenoscopic observations after administration of bismuth carbonate meals and enemata.

Diagnosis of the condition is readily established, except where the hernia consists of an incarcerated epiplocele. The fact that the tumor lies *lower* than the inferior limit of the lung is a most important point and one very apt to be disregarded. Reduction with a gurgle, increase in size on inspiration, and the presence of digestive disturbances are not invariable symptoms, but are of great diagnostic aid when present.

Differential diagnosis from such conditions as subcutaneous emphysema, hæmatoma, or pneumocele following a contusion, should not be difficult. Emphysema gives a characteristic crackle, and is usually diffuse; a hæmatoma does not change its size with respiratory movements; a pneumocele lies higher than

the usual intercostal diaphragmatic hernia. Again, even if a pneumocele is of long standing, that part of the lung within the hernia usually remains unchanged,[4] and hence it should be possible to obtain diminution on inspiration, a normal percussion note, crepitation upon reduction, and normal breath sounds upon auscultation.

The differential diagnosis between an irreducible incarcerated omental hernia and an irreducible pneumocele with thickened or atelectatic lung tissue may not be easy. The location of the swelling and the presence or absence of digestive disturbances may serve as clues.

A subpleural lipoma projecting through an intercostal space has been observed.[5] Its occurrence is very rare. It is usually found in the upper thorax, but should such a tumor occur in the lower thorax, there might be considerable difficulty in diagnosis.

Prognosis depends upon the same factors as in herniæ in general.

Treatment.—Treatment consists in the application of a suitable bandage or truss, or in operation. A glance at the cases published shows that the operative procedure has not always been easy. As said before, there was usually no true sac, and where some sort of sac existed, there were many adhesions between its walls and the hernial contents. The best plan, therefore, is to dissect close to the neck of the hernia and gain an entrance into the free peritoneal cavity. After this, freeing and reduction of the contents can be done more easily and as circumstances dictate. It is well to bear in mind that the gut or pleural cavity may be accidentally opened, and therefore to be fully prepared for such contingencies. The closure of the opening may present certain difficulties. If it is not possible to make a layer suture of the diaphragm and intercostal muscles, owing to an inelastic ring

[4] Auler, Julius: "Beitrag zur Kenntniss der Lungen brüche," Berlin, 1892.

[5] C. Gussenbauer: Cit. after H. Tillmanns, Lehrbuch der speciellen Chirurgie, 3rd Ed., Part I, vol. ii, p. 605, Fig. 334.

of cicatricial tissue by which the diaphragm and thoracic wall are fused together, the ribs above and below may be approximated, obliterating the space through which the hernia formerly protruded; or, a plastic closure may be resorted to, using fascia, periosteum, or part of the latissimus dorsi.

To sum up, intercostal diaphragmatic herniæ (1) are usually traumatic in origin; (2) they occur mostly on the left side in the anterior portion of the intercostal spaces (sixth to tenth inclusive), a region lying between the lower margin of the lung and the free border of the rib from the midline to the midaxillary line; (3) their symptoms are those common to herniæ in general; (4) the X-ray is of great value in determining the relationship of the various parts of the alimentary canal to the herniæ; (5) the details of operative treatment vary with the findings in individual cases.

It is the writer's opinion that the occurrence of these herniæ is not as rare as the few published communications on this subject would lead one to believe.

AN EXPERIMENTAL STUDY OF THE MANAGEMENT OF POST-OPERATIVE THORACIC INFECTIONS.*

A PRELIMINARY REPORT.

BY NATHAN W. GREEN, M.D.,

AND

HENRY H. JANEWAY, M.D.,

OF NEW YORK.

EMPYEMA of the pleura following some infectious process in the lung is not, as a rule, rapidly fatal. It is generally walled off by adhesions causing a closed abscess. This abscess can be drained and immediate danger of death averted. Purulent pleuritis following surgical trauma is different in its progress, and the event of death is proportional in frequency to the amount of shock accompanying the initial infection. Our own experience demonstrates to us the truth of this statement both from an experimental and clinical standpoint. Death may be caused by one of the following three factors, but usually is due to their combined action:

A. Physical—impairment of the respiratory mechanism, producing either complete or partial collapse of the lung.

B. Physiological—following fatigue of the respiratory apparatus, in part due to physical causes just mentioned.

C. Infectious—due to local and general bacterial invasion.

If we can overcome in the laboratory the combined effect of shock, coupled with one of these aforesaid three, we feel confident that these methods applied to the human being will give better results.

Let us compare the conditions found in the abdomen with those in the pleural cavity. We see here four points of difference. In the case of the pleural cavity, first, there is negative pressure; second, a rigid chest wall; third, a greater motility

* Read before the New York Surgical Society, May 10, 1911.

of the viscera; and fourth, there is the tendency to retract rather than to approximate and form adhesions. Sauerbruch and Robinson[1] have dwelt at considerable length upon the importance of this last factor.

If, now, we can by artificial means bring about conditions in the chest approximating those in the abdomen, we may hope for recovery after purulent infections, even as is now the rule in the abdomen.

Not one case of carcinoma of the cardia operated upon by the transthoracic route has been reported that has lived more than five days. The operation has been carefully done, the patient has rallied from the operation, but has died after forty-eight hours from undrained purulent pleuritis. This fact we may not lightly disregard. Drainage of some sort must be established in order that thoracic operations may be more successful. In previous papers [2 3] we have stated that we believe herein lies the solution of this problem. It would be ideal to hope for intrapleural healing without infection and without adhesions of the pleura.

If, now, we look at a suppurative process within the abdomen, we see that one of the conservative steps of the process is the early formation of adhesions. Why not transfer this principle, then, by artificial means to the thorax? How shall we accomplish this? By approximating the visceral and costal layers of pleura and keeping them in apposition until adhesions shall have formed; thus preventing the existence of dead spaces in the pleural cavity.

In looking over the results of this last winter's work, we find that we have operated upon over 50 animals, all under general anæsthesia. We must view our results with an impartial judgment.

Among the procedures which we have attempted, we have tried a permanent drainage of the chest with a tube designed

[1] F. Sauerbruch and Samuel Robinson: ANNALS OF SURGERY, vol. li, No. 3, March, 1910.

[2] H. H. Janeway and N. W. Green: Deutsche Zeitschrift für Chirurgie, Band 107, 1910.

[3] N. W. Green: Surgery, Gynæcology and Obstetrics, vol. ii, No. 5, pp. 512-538, May, 1906.

to be of such diameter that the inflow and outflow of air in the act of coughing was but of small amount, and so arranged that when the dog closed his glottis the lung could be inflated, blowing out fluid and air from the pleura. At the same time the aperture was not large enough to embarrass violently the respiratory act. We have tried, also, intermittent drainage with a permanent tube in place. We have tried permanent drainage with a permanent tube, as suggested by Bryant. We have not yet tried Robinson's[4] very ingenious device for drainage. We have tried intermittent drainage with a tube introduced at intervals, adding, at the same time, positive pressure by introducing the animal's head into the cabinet. We have added to this, also, suction on the introduced tube. We have tried two-way irrigation alone and two-way irrigation with positive pressure. We have also attempted to limit infection to the site of operation by the injection of Hiss's leucocytic extract. (This was partially successful and gave significant findings.)

The animals die with pus in the chest, with collapsed lungs, often with a general infection, or with exhaustion from labored breathing. A number we have saved for a certain length of time.

Where and from what does the infection come? To a certain extent by direct contamination from the opened viscera. We have found, however, that the pleura, if not too long exposed, will stand a severe contamination and the animal will survive. We have opened the chest under differential pressure, and opened the œsophagus, spread around œsophageal contents in the pleural cavity, sutured the œsophagus and closed the chest, and the animals have easily recovered.

Does it come from exposure of the pleura to the air? It does to a certain extent. We have opened the chest under differential pressure, and, without any further procedure, have left it open for two hours, then closing it we have found the dog infected, and the infection ran to a fatal issue.

[4] Samuel Robinson: Boston Medical and Surgical Journal, vol. clxiii, No. 15, pp. 561-570, Oct. 13, 1910.

Is it due to a lowering of the animal's general and local resistance? In a recent article in the *Journal of Infectious Diseases,* Graham [5] states that ether diminishes the phagocytic action of the leucocytes. We have on this account conducted some of our experiments under nitrous oxide and oxygen. We have tried to make our work as rapid as possible, we have padded off the thoracic cavity, we have used sterile almond oil on the tissues to prevent drying, and yet in many cases shock combined with the infection has brought about a fatal issue.

At autopsy we have found quite a uniform picture: pus or seropurulent fluid, complete collapse of the lung upon the operated side with partial collapse upon the other side, adhesions where the lung touched the diaphragm and the site of the operation in the œsophagus, but only few adhesions between the lung and the chest wall. In a few cases examined we have obtained bacterial cultures from the liver.

In cases autopsied more than twelve hours after death there were apparent stitch leaks. In each of three cases autopsied immediately after death, the anastomosis was perfect, as tested by water pressure.

It seems, then, that it is not continued contamination but the result of contamination plus the presence of an area in which the resistance has been lowered, that induces the purulent exudate.

In the case of the animal, we have three things to contend with that do not obtain in the adult human subject. The first is lack of post-operative intelligence; the second, lack of a stable mediastinum; the third, lack of proper cleanliness. If we can overcome these, we stand a greater chance of making our experimental work more successful, and we can transfer our methods to the human species with added confidence.

To overcome these three things in the laboratory, it will be necessary to keep the animal, by some means, quiet for from twenty-four to thirty-six hours, to establish some permanent pressure within the lungs, and to prevent any inward suction

[5] Evarts A. Graham: The Jour. of Infectious Dis., vol. viii, No. 66, p. 152, Mar. 6, 1911.

of contamination from the wound-surface. It is suggested to establish a permanent differential pressure with the head in either a cabinet or a chamber such as that of Dr. Meyer, or with the thorax in a negative chamber such as the Sauerbruch cabinet. To facilitate getting rid of the purulent exudate, we suggest double current irrigation at the site of anastomosis while pressure is maintained, and we think it advisable to consider all operations upon the œsophagus occupying more than an hour and a half as being infected. We advocate, therefore, drainage to the site of the anastomosis for the first twenty-four to thirty-six hours.

Briefly, a plan which we have as yet been unable to adopt, but which suggests itself from our findings, is this: after the completion of the operation, a drain should be inserted to the bottom of the chest and site of anastomosis, which should be left in place for twenty-four to forty-eight hours. The animal should be given suitable medication to keep him quiet and, at the same time, free from distress. The head should be placed in a cabinet for a sufficient time to allow adhesions to form between the visceral and parietal pleura, and at the end of twenty-four hours a two-way irrigation should be performed down to the site of the anastomosis. After this the pressure may or may not be kept up for twelve hours longer, and on the following day the drainage should be removed.

THE SURGICAL CLINIC OF THE PROTESTANT EPISCOPAL HOSPITAL OF PHILADELPHIA.*

REVIEW OF 150 CONSECUTIVE OPERATIONS.

BY CHARLES HARRISON FRAZIER, M.D.,

OF PHILADELPHIA.

THE series of cases herein discussed represent the surgical experience at the Episcopal Hospital in a three months' service, excluding a not inconsiderable number operated upon by one of the assistant surgeons or internes.

Morbidity.—Of the 150 operations of our series almost 100 were for lesions of the abdominal organs. Of the total number there were four deaths, a mortality of about 2.5 per cent. Two of these four deaths, as will be seen, may properly be excluded, so that the mortality may be reckoned as 1.3 per cent. The series include 30 operations for appendicitis and its complications, 22 for hernia, 8 for lesions of the stomach or duodenum, 18 for operations on the pelvic organs with 4 hysterectomies, 4 operations on the biliary passages, 14 upon the urinary organs, and 3 thyroidectomies.

Of the four fatal cases one was a case of tuberculous meningitis, which because of certain focal phenomena was regarded before operation as a brain abscess. An exploratory craniotomy seemed justifiable. The patient survived the operation but a short time, and the autopsy revealed the true nature of the lesion. The second was a strangulated umbilical hernia in an aged patient almost moribund, who scarcely survived the initial incision. These two might be regarded as inoperable.

The third death followed a suprapubic prostatectomy and bilateral herniorrhaphy under spinal anæsthesia in a patient 75 years of age. The patient's condition at the end of the operation was excellent and continued so beyond the period

* Read before the Philadelphia Academy of Surgery, May 1, 1911.

at which post-operative shock would have developed. But his vital processes gradually failed, and he died three and a half days after the operation. The fourth of the fatal series was in a patient who had been operated upon for gall stones. This case presented some interesting features and will be alluded to later.

Technic.—In the preparation of the field of operation the Grossitch or iodine method was used, preceded by a single preparation with soap, alcohol, and bichloride. The addition of iodine to the technic has so diminished instances of accidental infection that I am disposed to omit altogether any attempt at chemical disinfection with alcohol and bichloride. There was but one frank suppuration in our wounds, and in that instance there were a few small pustules at the site of the wound before the operation to which the infection may be attributed.

In the post-operative period, after operations with incipient or advanced peritonitis, after operations in the upper abdomen, and in all cases of advanced years with few exceptions, the patients were put in the sitting posture for at least 48 hours. This I believe minimizes the incidence of pulmonary congestion and in many instances adds materially to the comfort of the patient.

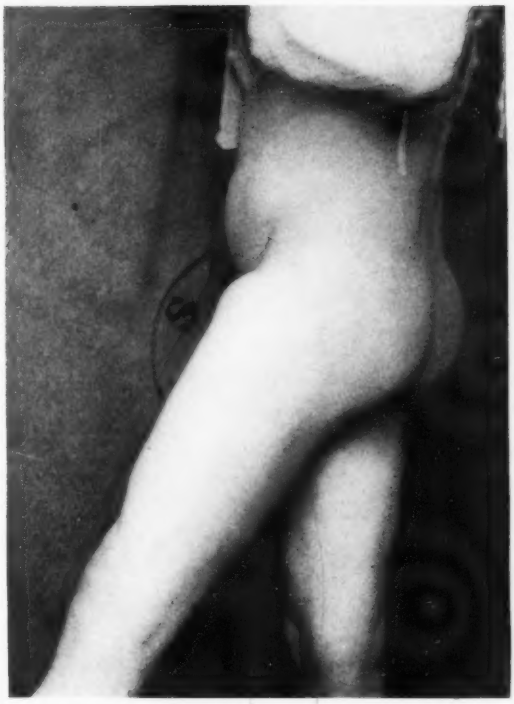
Proctoclysis was employed wherever for any reason the administration of water or liquids of any character by mouth was prohibited.

Anæsthesia.—The selection of an anæsthetic deserves much more attention than it receives at the hands of most surgeons. No matter how skilled the anæsthetizer may be in the administration of ether, there are certain cases where for the comfort and safety of the patient either spinal or nitrous oxide anæsthesia should be employed. While I do not believe nitrous oxide anæsthesia will ever come to be universally used as a substitute for ether, there are many occasions where it is an important factor in the saving of life. In cases of severe toxæmia, where patients are profoundly septic, as in some cases of gangrenous appendicitis, of peritonitis or gangrenous cholecystitis, in empyemata while resecting the rib, in supra-

pubic cystotomy for drainage or stone, in kidney decapsulation or nephrectomies in septic cases, or in strangulated hernias; in all these, as in many other minor procedures, there can be no question as to the value of nitrous oxide anæsthesia. Its safety in competent hands is unquestioned; it relieves the patient of the ether discomforts, but above all it minimizes the risk of operation where life is hanging in the balance and the depressing effects of ether would be enough to turn the scale. Where abdominal relaxation is necessary, ether is substituted for a few moments until relaxation is obtained, returning to nitrous oxide.

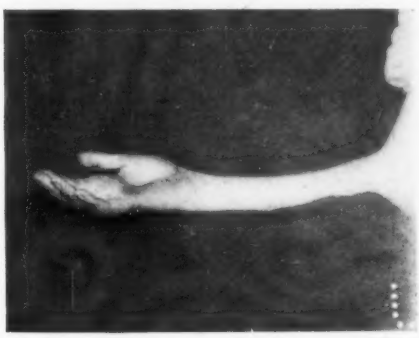
Spinal anæsthesia, too, has its special indications, it seems to me, particularly in patients with pulmonary tuberculosis and in elderly people, where, because of valvular lesions or myocarditis, the administration of nitrous oxide may be not unattended with risk. In this series I used spinal anæsthesia in the following operations: a colostomy for inoperable carcinoma of the rectum; suprapubic drainage of a large abscess of the pelvic region in a septic patient; in a laparotomy for tubercular peritonitis and another for cirrhosis of the liver; in a suprapubic cystotomy; in a suprapubic prostatectomy; in the repair of a vesicorectal fistula. Scopolamine gr. 1/150 two hours before and morphine sulphate, gr. 1/6 one half hour before the operation so benumbs the sensibility of the patient, that, though conscious during the operation, he suffers from none of the ill effects which might come from fright in a wide-awake patient. From spinal and nitrous oxide anæsthesia there were no ill effects. The only serious complication occurred in an operation for hydrocele. The patient was an alcoholic; after a considerable quantity of ether had been administered without avail, chloroform was substituted, and just as the incision was made the heart stopped beating. Cardiac massage was resorted to by the transdiaphragmatic method, and in the course of a few moments feeble fibrillary contractions could be felt. Gradually the cardiac contractions became more perceptible and regular, and after ten minutes resuscitation was established. The abdominal wound was

FIG. 1.



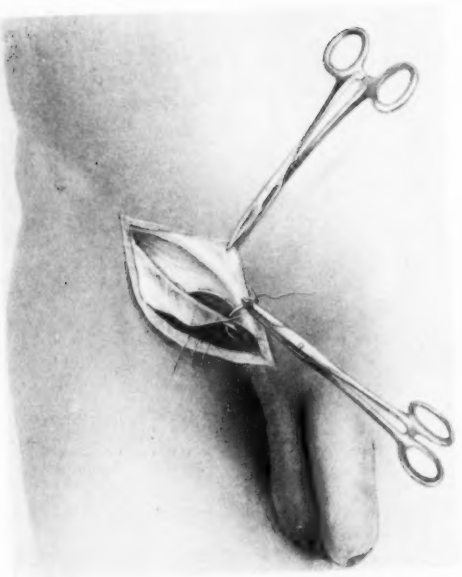
Photograph showing a fibrolipoma of the sartorius muscle mistaken before operation for a hernia. Note protrusion on the anterior surface of the upper portion of thigh.

FIG. 2.



Photograph of a congenital cavernous angioma of the hand with digital extensions.

FIG. 3.



Application of the sutures in the operation for radical cure of inguinal hernia.

FIG. 4

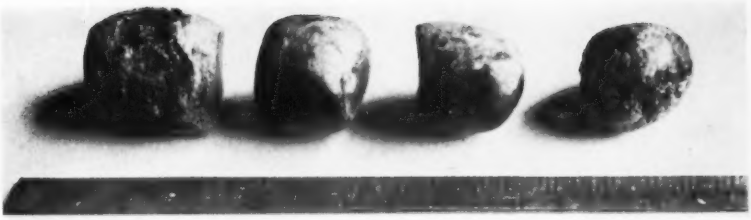
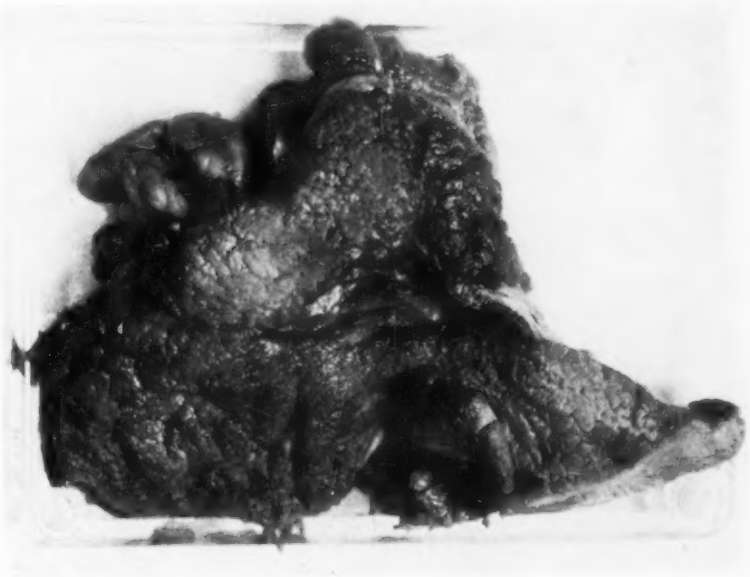


Illustration showing series of gall-stones arranged in column as they were found im bedded in a mass of inflammatory tissue after having escaped from the gall-bladder of a patient who had been free from symptoms until within two months of the date of the operation.

FIG. 5.



Portion of stomach removed, showing in centre of specimen the cavity of an indurated ulcer on the lesser curvature.

closed, and the operation on the hydrocele completed. The patient suffered no relapse, and the subsequent course of events was uneventful.

Tumors.—Curiously enough the district upon which the hospital draws for its material is not a fertile one for tumors. Relatively speaking there are few operations for cancer, exclusive of the uterus, and I have often attributed the paucity of malignant cases in the clinic to the popular impression among the less enlightened classes, that cancer is a disease of the blood and removed by operation always returns in some other place. Of the benign tumors there were three unusual enough to deserve mention. One was a lipoma in the belly of the sartorius muscle, about eight inches below Poupart's ligament (Fig. 1). The tumor protruded above the surface only when the patient contracted the muscle. On first examination the character of the lesion was not suspected; it was thought to be a muscle hernia. The second was a tumor of the breast, which, because of the associated enlargement of the axillary lymph-nodes, was thought to be either carcinoma or chronic cystic mastitis; but upon histological examination proved to be a fibroma. In the third case there was a large congenital angioma involving the palmar surface of the hand (Fig. 2) with digital extensions.

Appendectomies.—In the management of the appendix cases no hard or fast rules were laid down. It was not our practice to attempt to classify our cases as early or late to gratify the statistician, according to whether they were operated upon in the first 48 or 72 hours or later. In the acute cases with few exceptions the operations were performed as soon as the diagnosis was made. To this general rule there were certain exceptions. When the patient was first seen at the end or near the end of a mild attack we consulted our convenience as to the time of operation. Furthermore we advocated the starvation plan in a few cases of the following type: usually some time has elapsed since the onset of the attack; it may be only two days, more likely, however, three to five; the patient looks toxic, he is toxic; his pulse is rapid, over 120; the abdomen is distended and more or less

tender everywhere; peristalsis has been altogether or partially arrested, perhaps reversed with vomiting; restlessness and anxiety are written on the patient's face. In other words the infection is a wide-spread one. Sometimes this picture develops earlier, sometimes later, but whenever it comes I am convinced that the best results will be obtained by conservative practice, *i. e.*, by privation as to solids or liquids by mouth, proctoclysis, and posture.

One often hears or reads of bitter disputes as to whether the time limit between the early and late cases should be placed at 48 hours or later. Such discussions are futile, for early or late are but relative terms when applied to a given case. Each case must be a law unto itself, and no rules can be laid down comprehensive enough to allow for the innumerable variations.

It has been said, and very properly, that appendicitis is a surgical disease; no one denies it. The surgeon reserves as his privilege the right to decide upon the operability of a given case; that privilege is usually accorded him. In the exercise of this privilege he selects some cases for the Ochsner treatment and some of those cases may—before being operated upon—die. In the publication of his mortality statistics the surgeon usually excludes these. I believe, however, the time has come when the only means of determining the morbidity of appendicitis is to include in our death-rate those treated by both conservative and operative measures. We used to throw the responsibility on the medical men for all unoperated cases. But we cannot consistently do this any longer, if we take the stand, as I believe we should, that appendicitis is a surgical affection first, last, and always, and reserve the right ourselves to set aside a certain group, as I also believe we should, for conservative treatment. Having assumed entire responsibility for all cases, we must include in our statistics the fatal results in the unoperated as well as operated cases.

Irrespective of the appendices removed incidentally at other operations, there were 30 removed which were found at operation or in the laboratory to be diseased. There were no

fatalities in this series, but *apropos* of what has just been said of the mortality statistics I should refer to the case of a young man, who when first seen on the fifth day of the disease, was desperately sick. I declined to operate, and watched him carefully from day to day. Under the treatment prescribed his improvement with each 12 hours was marked, until four days later the distention had subsided to a marked degree, his tenderness had become circumscribed to the right iliac fossa, the pulse fell to 70, and the clinical picture was transformed from one of general to one of local peritonitis. I had planned to operate on the following day, but in the course of the early morning hours, the patient without warning developed signs of collapse from which he did not rally. No autopsy was performed and the cause of death was a mystery. At the same time it should occupy just as conspicuous a place in my statistics as a death following operation.

The technic of the operation calls for little if any comment save with reference to the matter of drainage. In this I find myself using drainage in an increasingly smaller number of cases, and when drainage is required using less drainage material, rarely anything but split rubber tubing with a wick of gauze. The fundamental principle in draining the peritoneal cavity is the relief of pressure afforded by the opening in the abdominal wall. This need not be larger than to accommodate one or two full sized drainage tubes. I no longer have a wound entirely open and filled with gauze, and I close wounds without drainage sometimes even when there is a small accumulation around the appendix, thoroughly disinfecting the region with alcohol.

Hernia.—Of the hernia series there were 22 cases, of which 13 were indirect and 3 direct inguinal, 2 recurrent, 1 femoral, 2 ventral, and 1 umbilical. There were no unusual types except an irreducible omental hernia in a young adult, a case in which the diagnosis was not established until the operation. Without impulse it presented the earmarks of a lipoma. Of the series there was one fatal case in a large strangulated umbilical hernia of four or five days' duration, in the person of an aged woman who was generously referred to my service

by a practising surgeon of a neighboring hospital. The patient was almost moribund at the time, and did not more than survive the hasty attempt to expose and free the contents of the sac.

The method of procedure in the inguinal type varied according to the character of the hernia; in some instances the simple Ferguson, in some the Bassini, and in others the imbricating method of Andrews was used. In the selection of the method I have always tried to observe the general principle of disturbing in the least degree the normal anatomical relations. Thus in the hernias of children and the incipient hernias of young adults where the rings are not large and the musculature all that could be desired it is not necessary to transplant the cord. After isolating the sac and freeing the neck from its attachments and ligating it an inch beyond the margins of the internal ring, the internal oblique and conjoined tendon were sutured to Poupart's ligament without transplanting the cord; and the wound in the external oblique sutured without imbrication. In complete hernias of longer duration with larger rings the Bassini method was adopted. The remaining group included hernias of still longer duration, where the rings are more or less approximated, all direct hernias, all hernias in elderly people with musculature flabby and without tone, and hernias in which the conjoined tendon is altogether obliterated. Here I invariably resorted to the imbricating method of Andrews, in some cases splitting the sheath of the rectus and using either the belly of the muscle or flap of the sheath to fortify the defective area at the lower portion of the canal. This operation in this particular group is vastly superior to the Bassini method and should always be given preference. In all the operations, the incision in the external oblique is made a little above, instead of directly over, the canal and carried down as Judd recommends above and to the inner side of the internal pillar of the external ring so as to leave this structure intact. In introducing the deep mattress sutures in the reconstructive stage, my practice differs somewhat from the conventional procedure, in that I introduce the needle from the external aspect of

the shelving edge of Poupart's ligament, and the knot is tied in the outer rather than the inner aspect (Fig. 3). This is a matter of but minor consideration, but has been adopted because it avoids the splitting or tearing of the edge of Poupart's ligaments, which sometimes happens when traction in the suture is made to approximate the edges. For this suture I prefer to use a double strand of No. 0 or No. 1 catgut to a heavier single strand, as I always feel a little more confident of the sterility of the finer material.

We are gradually being weaned from the tradition that gall-stones are innocuous in many instances throughout life to be discovered only at autopsy. That many cases of cholethiasis have been treated for many years for stomach trouble we know too well, but in exceptional instances one runs across a patient in whose history there is nothing either indicative or even suggestive of the existence of gall-stones.

Such was the case in K. S., aged fifty, who told me she had never been sick in bed, that she had never been treated for dyspepsia, and had none of the digestive disturbances so common in cholelithiasis much less any of the acute exacerbations of biliary colic or subacute cholecystitis, at least until two months before the operation, when she had attacks of pain in the upper abdomen which had confined her to bed for a while. I questioned her myself with great care, as the physical signs pointed to the biliary passages. There was a mass in the abdomen about the size of a fetal head, extending from the margin of the ribs to the umbilicus. It did not move freely with respiration, and was not continuous with the margin of the liver. Through a right rectus incision I came down at once upon a mass, surrounded by adhesions, which were separated with great difficulty. Finally a cavity was opened containing pus and four large gall-stones (see Fig. 4). These were firmly imbedded in the inflammatory mass, arranged in single column, and faceted at either end where they were in direct contact. There was no escape of bile at any time, and nothing which could be identified as a gall-bladder was seen. The gall-stones, which must have been there months if not years, had ulcerated through the gall-bladder and became imbedded in a mass of inflammatory tissue. For two days the patient's condition was most satisfactory, but on the third day there was for

the first time a copious discharge from the wound, which was believed to be bile. On the fourth day 90 ounces of this fluid were collected.

Her pulse was growing more rapid and weaker, her skin leaky. I was at a loss to account for her rapidly failing strength. I began to suspect the fluid draining in such quantities was not pure bile; specimen examined disclosed hydrochloric acid, and further investigation pointed to a fistulous communication with stomach and duodenum, probably resulting from the trauma incidental to the liberation of the gall-stones from the inflammatory bed. The patient was taken to the operating room again, and through a left rectus incision our suspicions were confirmed. The tissues about the perforation were so fragile that it could not be satisfactorily closed with sutures. Accordingly a gastrojejunostomy was performed and the pyloric outlet closed. The patient did not react and died the following day. Had the true nature of this lesion been recognized sooner, I cannot but feel she would have survived the second operation.

Of the lesions of the upper digestive tract there were in all nine cases, two gastric carcinomas, two gastroptoses, three gastric and two duodenal ulcers. All were operated upon and there were no fatalities. It is interesting to note that in the ulcer cases the proportion of males to females was four to one, a further evidence of the greater prevalence of ulcer in the male sex.

Before discussing the operative procedures in this series I will refer to some interesting facts bearing upon the diagnosis and symptomatology.

In one case, B. F., an engineer, fifty-five years of age, the pre-operative diagnosis was cholelithiasis. There was a history of stomach trouble covering a period of two years, with bilious attacks and occasional vomiting; the patient stated that he had been jaundiced off and on, that his stools had been clay colored, and that discomfort followed eating. There was some rigidity and tenderness over the gall-bladder, and the scleræ were jaundiced. At the operation a typical saddle-back ulcer was discovered, with an unusually extensive infiltration of the gastrohepatic omentum. To the encroachment of this upon the common duct we attributed the signs of obstructive jaundice which led

us astray in the diagnosis. The ulcer-bearing area with a portion of the gastrohepatic omentum was resected, and all the symptoms, including those of common duct obstruction, disappeared (see Fig. 5).

The unreliability of the gastric analysis in the diagnosis of gastric or duodenal ulcer or cancer was forcibly illustrated in our cases. As to the presence of hyperacidity or of occult blood in the contents of the stomach or bowel, I am becoming more and more convinced that to wait for such laboratory indications of ulcer is unjustifiable in the presence of a reasonably clear history. It is after all the history upon which we must place the most reliance, and upon which our decision for or against operation must be founded. Unfortunately the "history," so called, is often not an accurate record of the development of the disease in chronologic order, but a collection of isolated facts forced from the patient by a system of cross-examination at the hands of one who often approaches the case with preconceived notions as to the diagnosis and conducts his examination accordingly. A better term, as some one has recently pointed out, is anamnesis, which implies a record of the disease from the patient's recollection, and if the patient is intelligent enough it should be written by the patient and not for him. That one may sometimes be misled, however, by the history is shown in my experience with a young woman evidently neurasthenic in temperament. Although skeptical about the existence of a gross lesion, I was finally persuaded to explore the upper abdomen, because of the very positive evidence of hæmatemesis and of aggravated attacks of vomiting and pain. The findings at the operation were negative and I ascertained afterwards from the patient that she was in the habit of sucking the gums till they bled, swallowing the blood, and then inducing vomiting. Hence the hæmatemesis.

To me an interesting case, because of the difficulty in diagnosis and the duration of the disease, was of a young man then thirty-one years of age, who had been ailing twenty years off and on; at the age of eleven he had an attack of vomiting with abdominal pain which confined him to bed for ten days; and even

prior to that time had what he called indigestion. He had served in the army during the Spanish War, and since then had worked steadily as a machinist. His work had never been interrupted, he ate everything, had never vomited, and never had any blood in stools. His chief and only complaint was pain, worse when the stomach was empty, often having to get up at night for a glass of hot milk or water. There was no occult blood, no hyperacidity, no dilatation of stomach. He was tender over his epigastrium but he was tender also over his appendix. Although the clinical picture did not conform altogether to type, I thought we were dealing with a case of appendicular dyspepsia, a chronic appendix with gastric symptoms, and proceeded accordingly. Through a gridiron incision I explored the appendix, and found it buried in a mass of adhesions, and liberated it with much difficulty. Though there was no doubt as to the existence of a lesion of the appendix, I was still in doubt about the upper abdomen, which I explored through a right rectus incision and found the stomach and omentum plastered to the parietal peritoneum, and on further investigation an ulcer of the lesser curvature. From the extent of the peritoneal invasion there had evidently been at one time some leakage. The operation concluded with a gastrojejunal anastomosis. Recovery was uneventful.

The method of procedure in gastric ulcer necessarily varies. However, I strongly advocate excision of the ulcer when this is feasible, and especially in the large indurative type, including the saddle-back ulcer in patients approaching middle life. It is in this type that carcinoma is most frequently implanted, and for this reason alone, if for no other, we owe it to our patients to practise the more radical procedure. These ulcers should be looked upon as precancerous conditions and treated accordingly. When the ulcer is so situated or so adherent to adjunct structures as to make excision difficult, the pyloric outlet of the stomach should be closed by infolding as the surest safeguard against recurrence and as the most rational way (in the light of our present knowledge of the pathogenesis of ulcer) of securing permanent results. The same practice is indicated, I believe, in duodenal ulcer as well, although in my experience the tendency to recurrence in the latter is not as great as in gastric ulcer. The operations

in this series of gastric cases were carried out according to these principles. In technic the no-loop gastro-jejunostomy, vertical opening was used, the line of sutures protected as Mr. Moynihan suggests with the gastrocolic omentum.

The management of actively bleeding ulcers requires the exercise of one's discretion. Ordinarily I favor palliative procedures.

For example one of our patients, a young woman of twenty-two, with a five-year ulcer history, had three large hemorrhages in five days, once vomiting three quarts and with a large quantity of blood in the stools. On admission she looked exsanguinated, her hæmoglobin was low. I decided not to operate at once, ordered 20 cc. of horse serum given hypodermatically, morphine q.s. to allay pain and restlessness, and small quantities of saline solution by bowel, and an ice bag to the abdomen. After five days of freedom from hemorrhage or vomiting I operated and found an ulcer on the greater curvature. If, on the other hand, the plan of treatment had been of no avail and hemorrhages recurred, with increasing frequency or in increasing amounts, there would then have been but one recourse, immediate operation.

Of the pelvic cases, in fact of the entire series, the most puzzling was in the person of a patient fifty years of age referred to me by Dr. E. F. Walsh. She told me that she had not been well since the birth of her last child three years ago, and prior to that had had one miscarriage, that her menstruation had been regular until the last period now two weeks overdue. She laid emphasis on troublesome attacks of indigestion with vomiting, for which her physician had treated her from time to time. Eight days prior to admission, after a hearty meal, she was seized with a violent pain and vomited. For the next three days vomiting continued but the pain was less severe. She remained in bed with a normal temperature on a liquid diet and on the day before admission she had had another attack of severe pain similar to the first. When I saw her she appeared exsanguinated, her hæmoglobin was 20 per cent., the leucocytes 22,400, and pulse 140; the abdomen was distended, and she referred her pain to the epigastrium and precordium. My first thought in view of the history of digestive disturbance, the intense pain, and attacks of vomiting was hemorrhage from a duodenal ulcer. In

her present condition operation seemed out of the question, so I watched her carefully day by day and gradually the symptoms of the upper abdomen disappeared and were replaced by an area of dulness and tenderness in the lower abdomen. To make a long story short, when her condition justified it I opened the abdomen and found we were dealing with an ectopic gestation. From a pint to a quart of partially organized blood-clot was removed together with the sac. There was no post-operative shock, and convalescence was rapid and uneventful.

Unfortunately the Episcopal Hospital is so far removed from the center of the city as to be inaccessible both for the casual visitor and student alike. This isolation is a great drawback, as there is nothing so stimulating to the whole staff of a hospital, from the highest to the lowest officer, as the constant criticism and searching inquiry of those who are seeking useful information in modern methods of procedure. Because of its isolation the physical equipment of the hospital is known to few of the profession, resident and non-resident. Perhaps the most favorably situated of the larger hospitals for service to the working classes, it has a wealth of material representing the whole field of surgery. Of the lesions of the extremities, there is an extraordinary opportunity to study fractures of every description, and of the abdominal lesions there is a veritable mine of examples of inflammatory conditions of the pelvis, most of which are the result of improper care at childbirth at the hands of incompetent midwives or the patients themselves. To the philanthropically inclined I know of no better object for investment than the establishment of a maternity department for the poor of that district.

The service of this hospital, as of many others, is an interrupted one. The disadvantage of this system pertaining in many institutions is well recognized and so patent as to admit of no dispute. Far better is the European system, where in each hospital a limited number of surgeons devote their entire time to the instruction of young physicians and surgeons and the utilization of the material at their command for the advancement of medicine as a science and an art.

TRANSACTIONS

OF THE

NEW YORK SURGICAL SOCIETY.

Stated Meeting, held May 10, 1911.

The President, Dr. Ellsworth Eliot, Jr., in the Chair.

ŒSOPHAGOSCOPIC AND GASTROSCOPIC EXAMINATIONS.

Dr. Henry H. Janeway (by invitation) and Dr. Nathan W. Green demonstrated the use of the gastroscope, and made some observations upon its surgical use and value.

Dr. Henry H. M. Lyle said that in hospitals it had been no easy matter to induce patients to submit to gastroscopic examinations, but, as a matter of fact, his own observation and experience had shown him that the procedure was not at all difficult. The larger tube of Mikulicz was somewhat harder to pass than Chevalier Jackson's; on the other hand, the Mikulicz tube was superior to that of Jackson for the purpose of removing sections, as it gave a better view in some respects.

Dr. Janeway, in reply to a question, said he had never seen severe bleeding after the removal of sections from the cardia or œsophagus. After removing the section and mopping with a bit of cotton, the hemorrhage, as a rule, was not severe enough to interfere with the view.

In connection with this paper, Dr. Janeway said he wished to make it clear that it was merely a preliminary report, but that it indicated a successful solution to a problem which ought to be solved.

The confirmation of the diagnosis by the removal of bits of tissue in so large a proportion of the cases of carcinoma of the stomach was presented with some hesitation, inasmuch as the series of cases was as yet too small to enable one to judge whether subsequent experience would be so successful.

AN EXPERIMENTAL STUDY OF THE MANAGEMENT OF POST-OPERATIVE THORACIC INFECTIONS— A PRELIMINARY REPORT.

Dr. Nathan W. Green and Dr. Henry H. Janeway read a paper with the above title, for which see page 549.

Dr. Willy Meyer said there could be no doubt of the fact that, since the introduction of the differential pressure apparatus the thorax could be simply and safely opened. In a number of instances he had been struck by the fact that the patients stood the operation very well, but that on the second day signs of dyspnœa and cyanosis appeared, sometimes with fatal results. In one of the earlier cases operated on at the German Hospital, where both pleural cavities were opened, and the thoracic incision closed air tight, the patient did very well for sixteen or eighteen hours after the operation; he then became profoundly cyanotic, and before he could be brought back under the influence of the differential pressure, where the wound could have been reopened, if necessary, he passed away. In that case there was a carcinoma of the œsophagus, and a resection of the latter had been done. The patient was a man, sixty-four years old, and the operation was quite a severe one. At the post-mortem examination, both pleural cavities were found filled with a large amount of serosanguinolent fluid, and the lungs were compressed and collapsed.

This and subsequent cases, Dr. Meyer said, had convinced him that besides doing the actual work under differential pressure, we had to learn to drain these wounds. In the new pavilion for thoracic surgery at the German Hospital, arrangements had been made for two recovery rooms, which were located adjacent to the differential pressure apparatus, and here patients who had been operated on under differential pressure were kept for twenty-four or forty-eight hours after the operation on special beds which were of the same height as the operating table and unobstructed at the head-end, so that if necessary the head of the patient could be readily placed in the differential air chamber. The pressure of the airlock gave free access to the patient's head for purposes of feeding, etc., by the relays of assistants and nurses.

Dr. Meyer said he appreciated the fact that the differential pressure method, as carried out at the German Hospital, was only one way of permitting surgeons to enter the thoracic cavity safely.

Other methods were known and other solutions of this problem would probably come to light. But whether or not intrathoracic work would have a successful issue would depend not only on the surgical technic itself, but on the proper after-management of the patient, especially on drainage of the thoracic cavity.

DR. GREEN said that in the course of their experiments on animals, Dr. Janeway and he had noticed the same phenomenon mentioned by Dr. Meyer, namely, that in some instances after an intrathoracic operation the animal would progress favorably for sixteen, twenty-four or thirty-six hours, and would then begin to suffer from increasing dyspnœa and rise of temperature, followed by death. At the autopsy they found the lungs collapsed and the pleural cavities filled with a serosanguineous fluid. The speaker said he thought the collection of this fluid was undoubtedly due to the exposure of the pleura to the atmosphere for too long a time.

Dr. Green said he thought that Dr. Meyer's idea of immediately returning these patients into the differential pressure chamber upon the onset of these unfavorable symptoms was an excellent one. This would keep the lungs expanded, so that they would approximate the chest wall until adhesions should have formed; the track of the operation might then be easily drained.

REMOTE RESULTS OF RESECTION OF THE AORTA AND TRANSPLANTATION OF VESSELS.

DR. ALEX. CARREL read a paper with this title.

TRANSACTIONS
OF THE
PHILADELPHIA ACADEMY OF SURGERY.

Stated Meeting, held May 1, 1911.

The Vice-President, Dr. John H. Gibbon, in the Chair.

RESULTS AFTER REMOVAL OF AN EPITHELIOMA OF THE MANDIBLE, INVOLVING THE FLOOR OF THE MOUTH, THE CONTIGUOUS SURFACE OF THE TONGUE, AND THE GLANDS IN THE DIGASTRIC TRIANGLE WITH LIGATION OF THE EXTERNAL CAROTID.

Dr. Addinell Hewson presented a man, aged fifty-four years, who, when first seen February, 1909, presented a growth extending from the median line, on the left side, surrounding the roots of the central left lateral incisor and first bicuspid teeth, and extending into the floor of the mouth. It was of almond shape, ulcerated, and in the last six months had bled slightly. Enlargements in the digastric triangle were distinctly palpable. The growth had been very slow, but in the last two weeks had been rapid. The urinary examination was negative, and the blood examination showed no marked leucocytosis. The hæmoglobin was 87 per cent. Slight increase in the lymphocytes and decrease in the polymorphonuclear neutrophiles. The left external carotid artery was ligated as a preliminary to the operation. The incision for the removal of the growth was made in the median line and carried along the caudal margin of the mandible as far as the facial growth. A stout ligature was passed through the tongue, and a Gigli saw introduced, severing the mandible at the right canine tooth. The saw was again introduced, severing the mandible ventrad to the left facial growth, thus permitting the tongue floor of the mouth to be in the grasp of the part removed. The incision was now completed, removing a portion of the growth

on the under surface of the tongue, the mylohyoid muscle, the attachments of the glossal and suprahyoid muscles, and the contents of the digastric triangle without involving the incision for the ligation of the left external carotid artery. The glossal muscles and the suprahyoid muscles were fastened to the remainder of the mandible on the right side, the margins of the tongue to the remains of the caudal fornix of the vestibule of the mouth, the wound closed with interrupted sutures, and a wick introduced in the bottom of each wound. The wound healed with slight stitch abscess, but there was no involvement of the carotid incision. The pathological report of the growth showed the presence of infiltration in the pearly bodies, also some infiltration into the tissue in the floor of the mouth and into the mucous and salivary glands. Some epithelial cells were found in the lymph-glands, and in some there was no infiltration whatever. The patient had an uneventful recovery, and was able to leave the hospital April 1. There was a slight recurrence in the alveolar process about the canine tooth, which was removed in May, 1910. Microscopically, this growth proved to be a slight recurrence. There was, at this time, no enlargement anywhere; patient's health was good, although absolutely adentulous, and compelled to eat soft food. In December, 1910, he reported, complaining of a small tumor about the size of a chestnut in the right supraclavicular region, which was very painful on manipulation. However, no manifestation of any connection with the mouth, and the swelling was treated as a result of cold and soon disappeared. This proved to be a fact, as, when the patient next appeared this growth had disappeared. At this date, May 1, 1911, there has been absolutely no return anywhere. The contraction of the muscles had produced rather a pointed chin, and the interval between the severed portions of the mandible was just the breadth of a finger. The tongue can be protruded to its normal length from the mouth, and the voice sounds give the impression of the patient lisping with a quid of tobacco in the mouth.

THE TREATMENT OF LACERATED AND INCISED WOUNDS OF THE EXTREMITIES, WITH REPORT OF FIVE TYPICAL CASES.

Dr. James A. Kelly read a paper with this title.

ANÆSTHESIA BY THE INTRATRACHEAL INSUFFLATION OF AIR AND ETHER.

Dr. CHARLES ELSBERG, of New York, by invitation, read a paper with this title.

DR. W. W. KEEN said that eighteen months ago he had the pleasure of seeing Dr. Carrel at the Rockefeller Institute do a remarkable series of operations upon animals, using this method, with a very simple apparatus. The etherizer used the foot bellows, and there were two tubes, one going directly into the respiratory tube while by the other the air passed through a bottle of ether, with a clamp on each. Thus pure air or air with ether vapor could be used in any proportion. It was startling to see Carrel with one sweep of a large knife open widely both thoracic cavities, exploring lungs, heart, and pericardium without the slightest trouble. There was no disturbance of the circulation nor any change in the color of the animal so far as one could judge. Carrel was able then to handle the lungs and displace them and the heart freely. He then severed and anastomosed the aorta, first clamping the aorta above and below the point where he did the anastomosis. He had intended originally to introduce a piece of vena cava that had been in cold storage for a number of days, but the specimen proved not to be a good one, and finally he had to abandon this and sutured the two ends of the aorta to each other. The œsophagus was fully exposed and handled. The operation took about an hour and a quarter. The dog at no time was in the slightest apparent danger of death. The lungs were pink, and whenever it was deemed necessary a little more pressure was put on or the pressure was diminished at will, and finally when the operation was completed the lungs were considerably distended to displace all the air in the thoracic cavity, the walls of the thorax were sutured in layers, and in the course of two or three minutes after the conclusion of the operation the tube was withdrawn and the dog was breathing as naturally as if an abdominal and not a thoracic operation had been performed. Dr. Keen was very much struck at the time with the simplicity of the operation, with the possibility of doing almost any operation by means of this method. It is a vast improvement over the expensive differential pressure chambers. The usefulness of this apparatus will be broadened very much.

DR. CHARLES H. FRAZIER said that he had recently witnessed

Fig. 1.

Giant appendix vermiformis.

a demonstration of this apparatus by Dr. Elsberg and he had been impressed with its effectiveness and the apparent freedom from risk. The operation, an appendectomy, was being performed by Dr. Elsberg's assistant. Dr. Elsberg gave his attention wholly to the apparatus which worked perfectly, and while it appears rather complicated, one should readily master its mechanism. It will replace general anæsthesia by the ether drop method in a number of instances, particularly in thoracic operations, in all operations in which the patient is in the prone position (face down) as well as in those about the buccal cavity where there is always danger of the possibility of the inhalation of blood with inhalation anæsthesia. Dr. Elsberg has shown by experiment that the force of the outgoing air is sufficient to prevent particles of blood, or as he used in his experiments lampblack, entering the trachea or bronchi. This is a very practical consideration and should not be lost sight of.

GIANT APPENDIX.

Dr. JOHN A. JOPSON showed a giant appendix vermiformis. The patient from whom he had removed it was a woman about fifty-eight years of age, exhibiting the symptoms of acute appendicitis, and who was operated upon the fourth day after the onset. The appendix was retrocæcal, pointing upward and adherent to the posterior surface of the cæcum and colon, and from its peculiar shape, size, and color, not easily recognized. It was separated from its attachment to the posterior wall of the cæcum, and when turned downward appeared as a large pouch communicating with the extremity of the cæcum, which was rather short. It lacked a mesentery, was white in color, and apparently undergoing necrosis, a sharp line of demarcation being present at its base. The base was crushed, ligated, divided, and the broad stump inverted by interrupted sutures. A drain was left in the wound to guard against leakage, but none occurred, and the patient, who suffered from chronic nephritis, made a good recovery. The appendix, which was quite empty, measured 7.5 cm. in length, by 4 cm. in diameter (Fig. 1). The wall was nearly a centimetre thick at the base, and there were two points of beginning perforation at the tip. Microscopic examination of sections was made by Dr. Speese, who furnished the following report: "The examination does not reveal any glandular tissue

or any structure which is suggestive of the same. To some extent the section resembles the normal structure of the intestine, in that some lymphoid tissue is present and arrangements suggestive of the normal coats of the intestine. The outline of these areas is, however, greatly distorted, and the muscle tissue separated by granulation tissue, dense in structure and apparently of long standing. There is an organized exudate or what appears to be the serosa, and throughout the appendix blood-vessels are distended and leucocytic infiltration points to an acute exacerbation. It is noteworthy that many eosinophilic leucocytes are present in the tissues. The examination discloses a process which resembles the lesions of acute and chronic interstitial appendicitis."

The appendix in this case would seem to be a reversion to a primitive type, in which the differentiation between the cæcum and appendix was much behind that normally observed in the human subject. It was interesting to compare it with those observed in some of the lower animals, as figured in Huntingdon's diagrams, reproduced with additional drawings in Kelly and Hurdon's work. In their shape and proportions the cæcum and appendix in this case resembled somewhat those normally present in the aard-wolf, the harbor seal, the collared peccary, and the American tapir.

THE SURGICAL CLINIC OF THE PROTESTANT EPISCOPAL HOSPITAL.

Dr. CHARLES H. FRAZIER read a paper with the above title, for which see page 554.

CORRESPONDENCE.

SPLINTING SKIN GRAFTS AND GRANULATING SURFACES.

EDITOR ANNALS OF SURGERY,

Dear Sir: Supplementing the paper by Dr. John S. Davis in the March, 1909, issue of the ANNALS OF SURGERY, I may say that since October, 1906, it has been my practice to dress burns, ulcers, blisters, and skin grafts with a protective made by dipping Brussels net into a mixture which renders it non-absorbent. This allows any ordinary dressing to be used, as all discharge escapes through the openings of the mesh into the outer dressings, and the net itself adheres neither to the wound surface nor to the dressings.

The first mesh I used was made by dipping the net into a xylol solution of crown dental rubber, but during the past two years I have used a mixture of white wax, laundry paraffin, and turpentine. This is equally efficient and infinitely cheaper, does not deteriorate, and can be prepared with much less trouble.

An average formula is as follows: white wax, two ounces; laundry paraffin, four ounces; turpentine, two ounces. Melt the wax and paraffin together, then add the turpentine, and bring slowly to a boil, now dip the Brussels net (previously sterilized) into the boiling mixture, for if the net is dipped when the mixture is not boiling films of wax form across the openings. Place in a solution of mercury bichloride 1:100 until required for use. Before using wash with sterile saline solution (warm but not hot).

Simple as the material is, it saves an immense amount of suffering for the patient and time for the dresser. Mesh of different sizes will be required for different cases, and the proportions of the ingredients may be altered for different conditions.

H. H. SINCLAIR, M.D., C.M.,
Walkerton, Ont.

August, 1911.

OPEN TREATMENT OF FRACTURES.

EDITOR ANNALS OF SURGERY:

In the ANNALS of September, 1911, on page 407, there is attributed to me a statement in a discussion of Dr. Edward Martin's paper on "The Open Treatment of Fractures," read at the meeting of the American Surgical Association, which conveys an erroneous impression. I am made to say, "Equally good results can be obtained by the ordinary old-fashioned pulleys with Buck's extension."

I said that, instead of using a one hundred pound weight for reducing the opened fracture, as suggested by Dr. Martin: "Equally good results (in overcoming the over-riding before applying the plate and screws) can be obtained by the ordinary old-fashioned *compound* pulleys, attached to the limb with Buck's extension apparatus."

I at the same time reported a case, wherein I had used this method, because the ordinary Buck's extension method with pulley at the foot of the bed was valueless. The fracture was such as required me to open and use plates and screws.

Any practical surgeon will at once see the dissimilar significance of these two similar sentences. The first is untrue, the second is true, in my opinion.

Yours truly,

JOHN B. ROBERTS.

313 S. 17th St., Philadelphia, Pa.

TO CONTRIBUTORS AND SUBSCRIBERS:

All contributions for Publication, Books for Review, and Exchanges should be sent to the Editorial Office, 145 Gates Ave., Brooklyn, N. Y.

Remittance for Subscriptions and Advertising and all business communications should be addressed to the

ANNALS OF SURGERY,
227-231 South Sixth Street,
Philadelphia.